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IN TWO SECTIONS
SECTION ONE

JAN 30 1934

JOURNAL of the AMERICAN WELDING SOCIETY

VOLUME 13
NUMBER 1

JANUARY
1934

Published Monthly

FOR THE ADVANCEMENT OF THE SCIENCE AND ART OF WELDING

WOULD ORDINARY JOINTS *weather this?*

NRA MEMBER U.S. WE DO OUR PART

Oxwelded Joints Held Where Others Failed

WHEN this 3,000-gallon, aluminum gasoline-truck tank took the road, nobody knew it would land in a ditch six months later—with the results shown in the second illustration! Yet it did, and the oxwelded joints were put to as severe a test as anyone could ask.

Being bent double for thirty inches didn't destroy the oxwelded joints a bit. Though the tank was fully loaded, not a leak developed. But the trailer's tank, which was not oxwelded, split wide all along the longitudinal seam . . . which proves, about as well as anything can, that oxy-acetylene welded joints give a product the extra strength it needs in times of trouble.

Oxwelded aluminum gasoline-truck tank before and after the accident. Not a welded joint failed.

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JOURNAL of the AMERICAN WELDING SOCIETY

Issued Monthly

Vol. 13
No. 1

JANUARY
1934

WM. SPRARAGEN
Editor

AMERICAN WELDING SOCIETY

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SOCIETY AND RELATED ACTIVITIES

ARE YOU INTERESTED IN WELDING?

During the 15 years' existence of the American Welding Society the advancement in welding has been rapid and continuous, both in practical applications and theoretical knowledge. In no small measure has the work of the Society been responsible for this advancement. National and Section meetings, our Journal and our Research and Technical Committees' efforts have all played a part. In fact, codes, standards, specifications and rules governing welding procedure, published by our Society, have brought about the general acceptance of welding by conservative executives and engineers. Today American Welding Society pronouncements are looked upon the world over as authoritative.

If further development of welding means anything to you, would it not be to your advantage to consider membership in this Society, so that you could participate in its activities and receive regularly its Journal, thus keeping yourself up to date on new methods and applications? Booklet setting forth the advantages of membership will be gladly furnished on request.

A. E. Gaynor
Chairman, Membership Committee

Two Members Honored

Two members of the AMERICAN WELDING SOCIETY have recently received promotions.

Mr. H. M. Priest, past chairman of the New York Section and vice chairman of the Structural Steel Welding Research Committee of the American Bureau of Welding, has recently been appointed as Engineer for the Railroad Research Bureau of the U. S. Steel Corporation. Mr. Priest is now located at the Frick Building Annex, Pittsburgh.

Mr. P. W. Swain, the other member, has served as chairman of the Meetings and Papers Committee, vice chairman of the New York Section, member of the Executive Committee and of the Board of Directors of the Society. He has been made editor of *Power*, published by the McGraw-Hill Publishing Company.

The AMERICAN WELDING SOCIETY wishes both of these men success in their new work.

Obituary

We learned with great regret of the death of Mr. Joseph Pohl, one of the loyal members of the AMERICAN WELDING SOCIETY, and one of the oldest members of the Philadelphia Section, on November 24th following a three weeks' illness. He resided at 207 White Horse Pike, Haddon Heights, N. J., and for the last quarter of a century was employed as an ordnance designer by the New York Ship Building Company.

Available Technical Publication of the A. W. S.

Report of the Structural Steel Welding Committee
Code for Fusion Welding and Gas Cutting in Building Construction
The Practical Design of Welded Steel Structures—H. M. Priest
Erecting Steel Buildings and Strengthening Steel Bridges by Welding—F. P. McKibben
Report on Welding and Cutting Nomenclature, Definitions and Symbols
Tentative Specifications for Filler Metal for Use in Fusion Welding
Metallurgy of Welding Wire
Standard Tests for Welds (November 1931 Journal)
Report of the Committee on Welded Rail Joints
Specifications for Fusion Welding of Pressure Vessels containing tests for qualifying welders in this field (March 1931 Journal)
Investigations of Welded Pressure Vessels
General Procedure Control for Gas & Arc Welding Aircraft Joints (December 1928 Journal)
Applications of Arc Welding to Ship Construction
Training Course for Oxyacetylene Welders
Training Course for Electric Arc Welders
Fundamentals of Oxyacetylene Welding
Fundamentals of Thermit Welding
Fundamentals of Resistance Welding

Research in Welding

The Fundamental Research Committee of the American Bureau of Welding is compiling a list of welding researches under way in universities, governmental departments and commercial companies. It is the intention of the Committee to publish this chart in an early issue of the Journal with the hope that it will stimulate cooperation.

This suggestion was made by a number of members at a recent conference of the Fundamental Research Committee as it was thought in this way unnecessary duplication would be avoided and that progress in research work will be stimulated by the knowledge of what the other fellow is doing.

Companies affiliated with the AMERICAN WELDING SOCIETY are requested to report at an early date any welding researches which they have under way which should be included in this chart. This information should be sent to W. Spraragen, Secretary, American Bureau of Welding, 33 West 39th Street, New York.

Bound Volume Journal

The AMERICAN WELDING SOCIETY has made arrangements for members who wish to have their Journals for 1933 bound in attractive, imitation black leather covers to do so by sending copies of the twelve issues to Russell-Rutter Company, Thirty-third Street and Eighth Avenue, New York, N.Y., Att. Mr. Russell Lauben, Jr. A special reduced rate has been arranged at $1.75 per volume providing the issues of the Journal are sent to the binder on or before February 15th. The bill for the binding and return postage will be sent direct from the Society's office.

New Members—December 1933

Class "B"

F. E. Aurand—Field Engineer, Commonwealth Edison Co., Chicago, Ill. Proposed by Walter Ahlstrom.

Saul Blickman—President, S. Blickman, Inc., Weehawken, N. J.

F. J. Heuperman—Engineer & Genl. Supt., The Canadian Western Natural Gas, Light, Heat & Power Co., Ltd., Calgary, Alta.

J. P. Jackson—Genl. Mgr., Tube Products, Ltd., Oldbury, Worcestershire, Great Britain.

C. H. Spencer—Genl. Supt., Northwestern Utilities, Ltd., Edmonton, Alta. Proposed by Membership Committee.

R. A. Wilkins—Director of Research, Revere Copper & Brass, Inc., Rome, N. Y. Proposed by W. H. Bassett.

Class "C"

F. L. Ballard—Welding Engr., ASEA Electric, Ltd., London W. C. 2, England. Proposed by F. E. Elge.

H. N. Barnes—Asst. Supt., Cherry-Burrell Corp., Little Falls, N. Y. Proposed by E. VomSteeg, Jr.

H. R. Bullock—Instructor, Mass. Institute of Technology, Cambridge, Mass. Proposed by L. F. Jackson.

A. W. Carpenter—Engr. of Bridges, New York Central Railroad Co., New York City.

Gustave Cavin—Chief Mech. Engr., Canadian Locomotive Co., Ltd., Kingston, Ont. Proposed by Membership Committee.

C. S. Conrad—Manager of Sales, Stainless Steel Dept., Columbia Steel Co., San Francisco, Calif. Proposed by W. P. Wooldridge.

F. R. Coster—Genl. Supt., Gas Distribution, Westchester Lighting Co., Mt. Vernon, New York. Proposed by Membership Committee.

R. G. Godson—183 Victoria East, Amherst, N. S. Proposed by W. Spraragen.

Joseph Haag, Jr—Pres., Todd Dry Dock Engineering & Repair Corp., Brooklyn, N. Y. Proposed by Membership Committee.

Roy E. Hansen—Manufacturing Engr., 1924 Compton Avenue, Los Angeles, Calif.

C. R. Johnson—Lt. Commander, U. S. Navy, Boston, Mass. Proposed by H. N. Ewertz.

O. F. Moore—Supt. of Maintenance, Minneapolis Street Railway Co., Minneapolis, Minn. Proposed by D. K. Lewis.

C. O. Mansur—Sales Engr. Eccles & Davies, Los Angeles, Calif.

D. H. Merrill—Mgr., Secretary-Treasurer, Pacific Coast Building Officials Conference, Los Angeles, Calif. Proposed by Frank L. Howard.

F. T. Ostrander—Vice-President, National Supply Corp., New York, N. Y. Proposed by A. E. Gaynor.

H. N. Pratt—Salesman, Columbia Steel Co., Russ Building, San Francisco, Calif. Proposed by C. S. Smith.

E. E. Pierce—Butler Manufacturing Co., Kansas City, Mo.

George Taylor—Foreman, John H. Mathis Co., Camden, N. J. Proposed by Membership Committee.

R. O. Waldman—Western Dist. Mgr., Fusion Welding Corp., San Francisco, Calif. Proposed by C. S. Smith.

J. P. Walsted—Professor, Mass. Institute of Technology, Cambridge, Mass. Proposed by H. D. Large.

Class "D"

Ernie Louck—Proprietor, Welding Shop, 2332 Fresno Street, Fresno, Calif. Proposed by H. W. Saunders.

Arthur Rowe—Electric Welder, 357 Presidio Avenue, San Francisco, Calif. Proposed by E. B. Griffeth.

Class "F"

A. F. Brown—Student, 5848 S. Hoover Street, Los Angeles, Calif. Proposed by J. W. McCartney.

SECTION ACTIVITIES

CHICAGO

On December 15th the Chicago Section held its second meeting of this season. "Application of Welding to Structural Work" was presented by Robert Hale of the Structural Welding Company and Henry Penn of the American Institute of Steel Construction.

DETROIT

Meeting held on December 14th. Following the formal business of the meeting, Mr. G. E. Phelps, of the Air Reduction Company, read a paper on mechanical cutting and flame machining, and showed slides of various operations of radiograph, regulators, torches and tips. Mr. P. W. Fassler, of the Fisher Body Corporation, gave an interesting talk on various welding developments, particularly in Europe.

LOS ANGELES

Another "Boost Welding" meeting of the Los Angeles Section was held on December 21st. Mr. E. P. S. Gardner, Chief Engineer, Quasi Arc Company, London, England, who is visiting in the United States, presented a short talk.

Mr. Frank A. Page, Supervising Engineer, Boiler Division of the California Accident Commission, gave a brief talk on "Welded Butane Pressure Tanks," stressing those details pertaining to welding and inspection.

Mr. C. J. Coberly, President of Kobe, Inc., spoke on "Oxy-Acetylene Cutting of Steel." Following this talk, those present at the meeting visited the plant of Kobe, Inc., where they were shown the slotting of oil well casings by means of the oxyacetylene cutting process.

NEW YORK

A joint meeting of the New York Section with the Iron and Steel and Power Divisions of the American Society of Mechanical Engineers will be held on January 16th at 8:00 P.M. in the Engineering Societies Building. Mr. R. H. Rogers of the General Electric Company will present an address on "Applications of Fusion Welding in the Boilers, Piping and Equipment of the General Electric Company's Outdoor Mercury-Steam-Electric Power Plant." Mr. H. M. Priest, of the American Bridge Company, will present an address on "Application of Structural Welding in the General Electric Company's Outdoor Mercury-Steam-Electric Power Plant."

PHILADELPHIA

The January meeting of this Section will be held on the 15th. Mr. O. A. Tilton, Industrial Engineering Department, General Electric Company, will talk on "Hard Surfacing by Welding." Mr. E. V. David, Applied Engineering Department, Air Reduction Sales Company, will talk on "Armoring Machinery and Equipment to Resist Wear."

PITTSBURGH

Over 100 members and guests assembled in the Fort Pitt Hotel, Wednesday night, December 6th, to hear Mr. J. C. Hodge, Engineer, Babcock and Wilcox Co., discuss fabrication of the penstocks for the Boulder Dam and the project itself.

Mr. Hodge illustrated his discussion of the penstocks with lantern slides and pointed out in detail the manner in which this part of the work is being handled by his company.

Three complete reels of motion pictures of the general construction work on the dam proper were shown and proved exceptionally interesting.

SAN FRANCISCO

"Qualifying Welders and Certifying Inspectors" was the subject of the December 15th meeting of the San Francisco Section. Mr. Frank Pape, State Boiler Inspector, presented this subject from the view point of his very wide experience.

Mr. W. C. Main, Standard Oil Company of California, just returned from the east, where he attended meetings on this subject, was able to give much interesting data.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

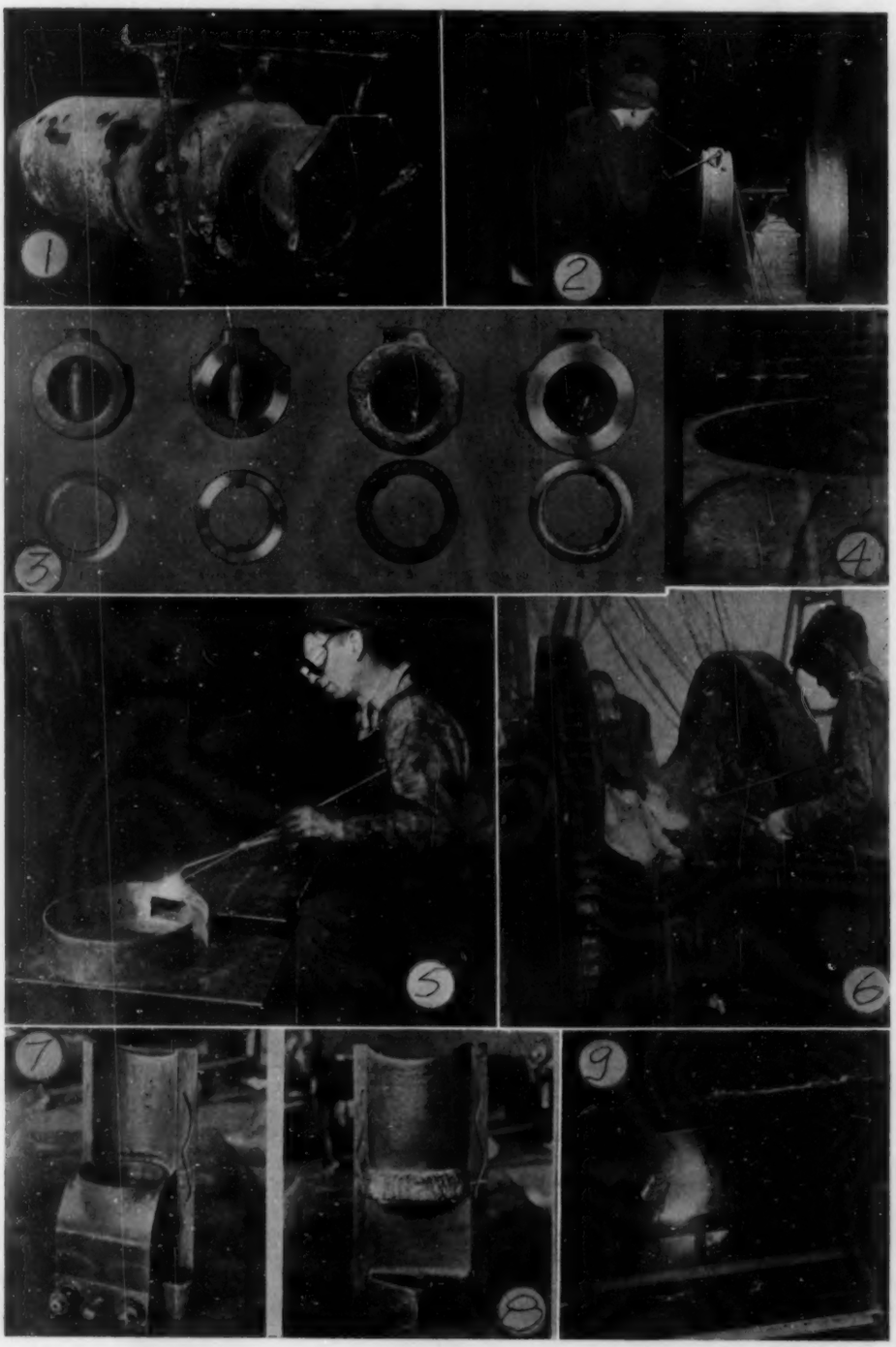
A-208. Acetylene welder since 1915. Can handle any welding school job as an instructor or a supervisor. Would like to get work of that kind. Retired as a Chief Petty Officer from the Navy since March 1933.

A-209. Electric welder and erector on tank and structural work with Welded Tank & Construction Company for seven years.

Welding Progress in 1933

A Pictorial Review

EDITOR'S NOTE. There follows a series of photographs showing some of the welding applications in 1933. Space limitations made it impossible to use many of the interesting photographs. Repetition of illustrations shown in the various issues of the JOURNAL OF THE AMERICAN WELDING SOCIETY for 1933 has been avoided.



Maintenance

Fig. 1—A new end welded to this large steel mill roll by the Thermit process saved it from the scrap pile. The roll is 40 in. in diam., the new end 30 in. in diam. Twenty-one hundred pounds of Thermit were used in making the weld. Courtesy Metal & Thermit Corporation.

Fig. 2—The application of the bronze-welding process to the rebuilding and resurfacing of pistons, bull rings and similar reciprocating parts of pumps and engines is one of the outstanding developments of the past year. Courtesy Union Carbide Company.

Fig. 3—Facings of cobalt-chromium-tungsten alloy applied to seat rings and disks by means of the blowpipe and such built-up surfaces combine excellent stainless properties with exceptional hardness. A 5000-hr. service as against only 500 hr. for ordinary valve seats is not unusual. Courtesy Haynes Stellite Co.

Fig. 4—Pump shell repaired by welding. Hole was worn entirely through 5-in. shell repaired with nickel manganese steel electrode by the Hallen Welding Service, Inc. Courtesy Stulz-Sickles Co.

Fig. 5—By designing for gas welding, savings in weight, easy last minute alterations, rapidity in fabrication and greater strength-weight ratio are accomplished. The fabrication of this special grind test machine illustrates this statement. Courtesy Union Carbide Company.

Fig. 6—Close-up showing welding of anchor windlass drum on S. S. *President Fillmore*, using square cast-iron welding rod and oxyacetylene process. Courtesy Air Reduction Company.

Figure 7 shows front view of cast-iron punch press ram which was broken and repaired with special heavy flux-covered electrode. Courtesy Lincoln Electric Company.

Figure 8 shows another view of the ram 22 in. wide and $1^1/_2$ in. thick at the break.

Figure 9 illustrates the electric welding of wrought-iron tunnel liner plates, $^1/_4$ in., $^5/_8$ in., $^1/_2$ in. and $^5/_8$ in. thick, to the steel beams supporting the roof of the tunnel on the New York Central Railroad at Oswego, New York. The plates were fabricated by the Morrison Metalweld Process, Inc. to reinforce the structure and to protect the steel beams from the corrosive smoke of the locomotives. Courtesy A. M. Byers Company.

Tanks

The first three illustrations are elevated water tanks built by the Chicago Bridge & Iron Works, the bottoms and supporting members of which are welded. Figure 1 is a 1,500,000-gal. tank built for the City of Evanston, Ill. Figure 2 is a 300,000-gal. tank for the City of Baltimore. The riser, the ten columns, the bottom and the girders under the bottom are welded. The tank in Fig. 3 was built for the City of Tallahassee, Florida, and has a capacity of 400,000 gal.

Figure 4 is two all-welded wrought-iron smoke stacks, one 77.7 ft. high and 30 in. in diam., and the other 62.2 ft. high, 30 in. in diam., fabricated from $^1/_4$-in. wrought iron plates by the Norfolk-Southern Railroad. Courtesy A. M. Byers Company.

Figure 5 is an all-welded 5000-barrel Hortonsphere erected by the Chicago Bridge & Iron Works for the Empire Companies, Ponca City, Okla., for the storage of Butane. The sphere is 38 ft. in diam. and is made of $^{19}/_{32}$-in. butt-welded plates. There were no fitting-up holes.

Figure 6 shows some oil storage tanks completely field welded with the arc. Courtesy Wickes Boiler Company.

Figure 7 is an all-welded 80,000-barrel Hortonspheroid erected by the Chicago Bridge & Iron Works for the East Texas Refining Company at Longview, Texas. The joints are lap welded; the sides and roof are made of $^3/_{16}$-in. plate and the bottom of $^1/_4$-in. plate. It is 136 ft. in diam. x 40 ft. high.

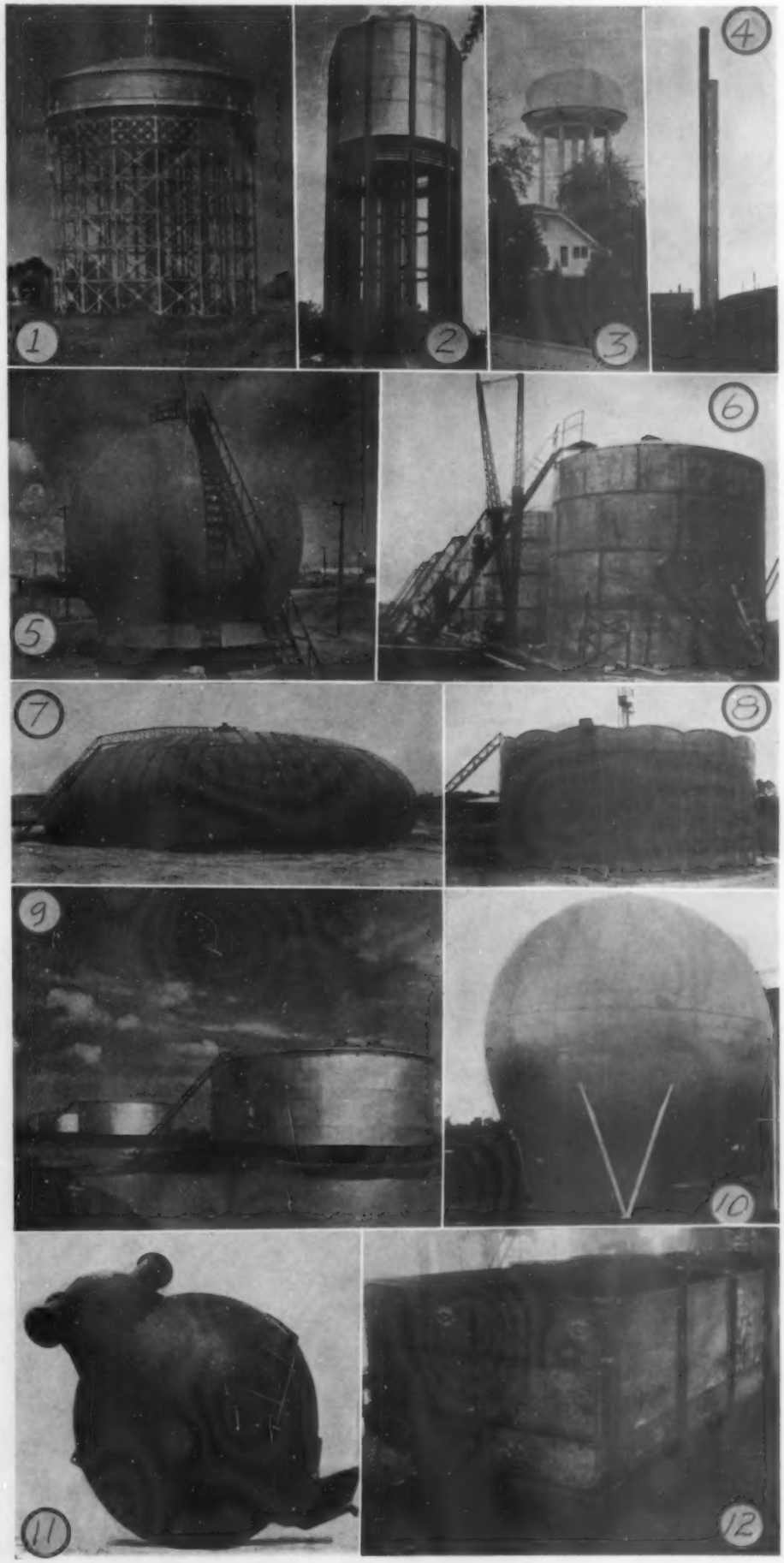
Figure 8 is the 38,000-gal. tank for the Warren Petroleum Company at Houston, Texas, by the Chicago Bridge & Iron Works. It is 86 ft. in diameter, the shell is butt welded and the roof and bottom lap welded.

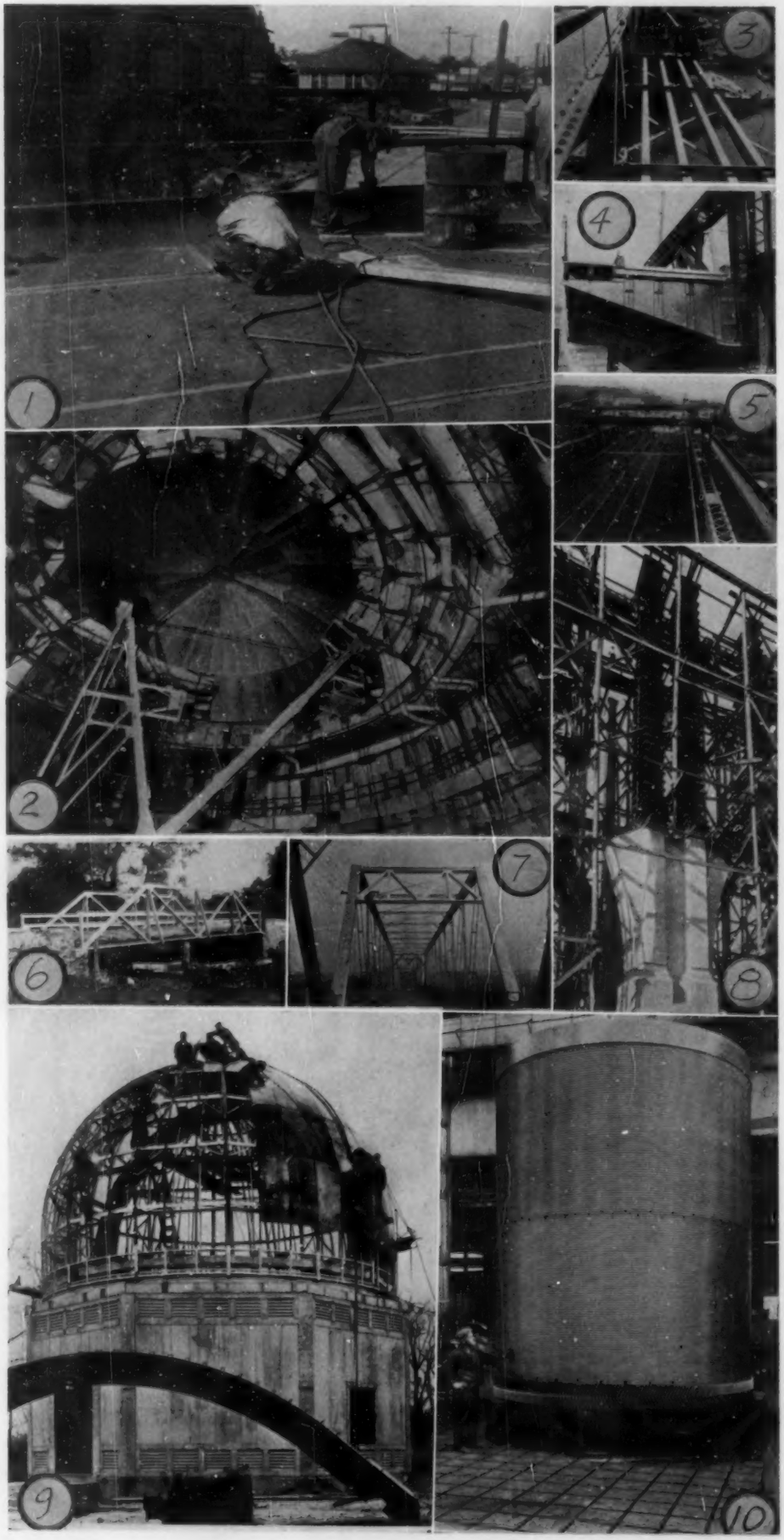
In 1933 there has been a steady increase in the use of butt welding for field erected tanks. A notable example is the group of seven 93,000-barrel oil storage tanks, Fig. 9, for the Sinclair Refining Company at Houston, Texas. Each tank is 120 ft. in diam. x 46 ft. Courtesy Chicago Bridge & Iron Works.

The 45 ft. diam. x $^9/_{16}$-in. butt-welded sphere for mixing gas at St. Louis, Missouri, Fig. 10. No fitting-up holes. Courtesy Chicago Bridge & Iron Works.

Unique in both construction and application, boulder trap (Fig. 11) was constructed of arc-welded steel by the Graver Tank and Manufacturing Corporation of Chicago. The trap is installed in the bottom of a large sea-going dredge.

Figure 12 is an all-welded wrought-iron beer cooling tank, 30 ft. x 12 ft. x 7 ft., made from wrought-iron plates $^3/_8$ in. thick, by Otto Meyer Manufacturing Company for Liebmann Breweries, Inc. To eliminate forming at the corners quarter sections of 10-in., 41-lb. wrought-iron pipe were welded to the side and end plates and welding elbows of wrought iron were quartered and used for the corners. Courtesy A. M. Byers Company.





Structural

Figure 1 illustrates an all-welded ballast deck type bridge fabricated by the Missouri Bridge & Iron Company from wrought-iron plates $^5/_8$ in. thick for the Missouri Pacific Railroad. Courtesy A. M. Byers Company.

Figure 2 shows the dome of the Fels Planetarium in the Franklin Institute in Philadelphia. This dome is built of 400 separate stainless steel contour sheets assembled by the "Shotweld" method. The whole dome weighs 11,000 lb. and is 65 ft. in diam. Courtesy E. G. Budd Manufacturing Company.

Arc welding played an important part in reducing the weight of the recently remodeled and widened University bascule bridge at Seattle, Washington.

Widening was accomplished by building roadways outside the bascule trusses as shown in Fig. 3. These traffic lanes are supported on arc-welded brackets securely tied to the floor beams through slots cut in the vertical truss members. The brackets have tapered bottom flanges, Fig. 4, and vertical stiffeners are welded to the web. Hand rails for the bridge were also arc welded, Fig. 5.

Welding was done by the Puget Sound Bridge and Dredge Company, contractors for widening of the span.

Figs. 6 and 7—Welding all-welded highway bridges in Chester County. Courtesy Mr. H. K. Ellis, County Engineer.

Fig. 8—Arc-welded steel concrete forms used on Cleveland's new Brookpark Bridge. Forms were built for ten columns. There are seven arches, all of the same design, so that each form was used in the bridge 14 times. The forms were built of $^5/_{32}$-in. plate to which were welded 3-in. channels vertically; 6-in. channels were welded horizontally to the smaller ones. Welding was done by the Highway Construction Company of Cleveland, Ohio, contractors for construction of the bridge. Courtesy The Lincoln Electric Company.

The observatory shown in Fig. 9 is 35 ft. high and 33 ft. in diam. Frames of the buildings are arc welded with the base of the columns held down by 4-in. anchor bolts embedded in concrete. A circular structural table built on top of the columns forms a base for the rollers of the turntable dome.

The exterior of the buildings is covered with steel sheets welded in place. Steel sheets are welded to the inside of the columns, leaving an air space between the outer and the inner vertical walls.

All welding is being done by the J. K. Welding Co. Courtesy The Lincoln Electric Co.

Fig. 10—One of two huge lifting-hoist drums, the largest of its kind ever built, for the cableway which is now under construction at Hoover Dam.

Each of the two drums was rolled from steel plate 2 in. thick, 42 ft. long and 8 ft. wide. The drums weigh 90,000 lb. apiece and will be wound with more than a mile of $1^1/_8$-in. wire rope, and will carry weights up to 150 tons. Courtesy General Electric Co.

Transportation

Fig. 1—Installation of Thermit pressure welds on steam railroad track at Albany, N. Y. One-half mile of main-line track was welded to form a continuous stretch, unbroken by expansion joints. Courtesy Metal & Thermit Corporation.

Figure 2 shows a high pressure welded horizontal tubular boiler built for the Wieland Dairy Company of Adel, Wisconsin, 78 in. in diameter, 20 ft. long, shell and heads $^5/_8$ in. thick, built for 150 lb. working pressure. Courtesy The Hedges-Walsh-Weidner Company.

Fig. 3—Steel plate plus welding equipment plus 40 men plus two weeks equals two 60-ft. barges in Galveston. It was made by The Kane Boiler Works, Galveston, on barges built for the United Dredging Company of New York. The barges are 60 ft. long, 30 ft. wide and 6 ft. deep. Courtesy The Lincoln Electric Company.

Fig. 4—The *Dolomite* is the largest all-welded freighter ever built. It was launched early in December by the builders, the Dolomite Marine Corporation, Rochester, N. Y.

Principal dimensions of the ship: Length, 212 ft.; Beam, 32 ft.; Moulded depth, 13 ft. 4 in.; Gross tonnage, 1700. Courtesy The Lincoln Electric Company.

Figure 5 shows the "Shotweld" construction as applied to the rear car of the Texas & Pacific unit recently delivered. Courtesy E. G. Budd Manufacturing Company.

Fig. 6—Transmission line construction truck. Courtesy the "HH" Manufacturers, Inc.

Fig. 7—Stainless steel streamlined train makes possible high speed, safety and luxury. Capacity, 47 passengers. Length, 51 ft. 1 in. over all. Speed, 50 miles per hour. Courtesy E. G. Budd Manufacturing Company.

Figure 8 is skeleton view of amphibion airplane built entirely of stainless steel whose weight is 1750 lb., capable of carrying four passengers. Courtesy E. G. Budd Manufacturing Company.

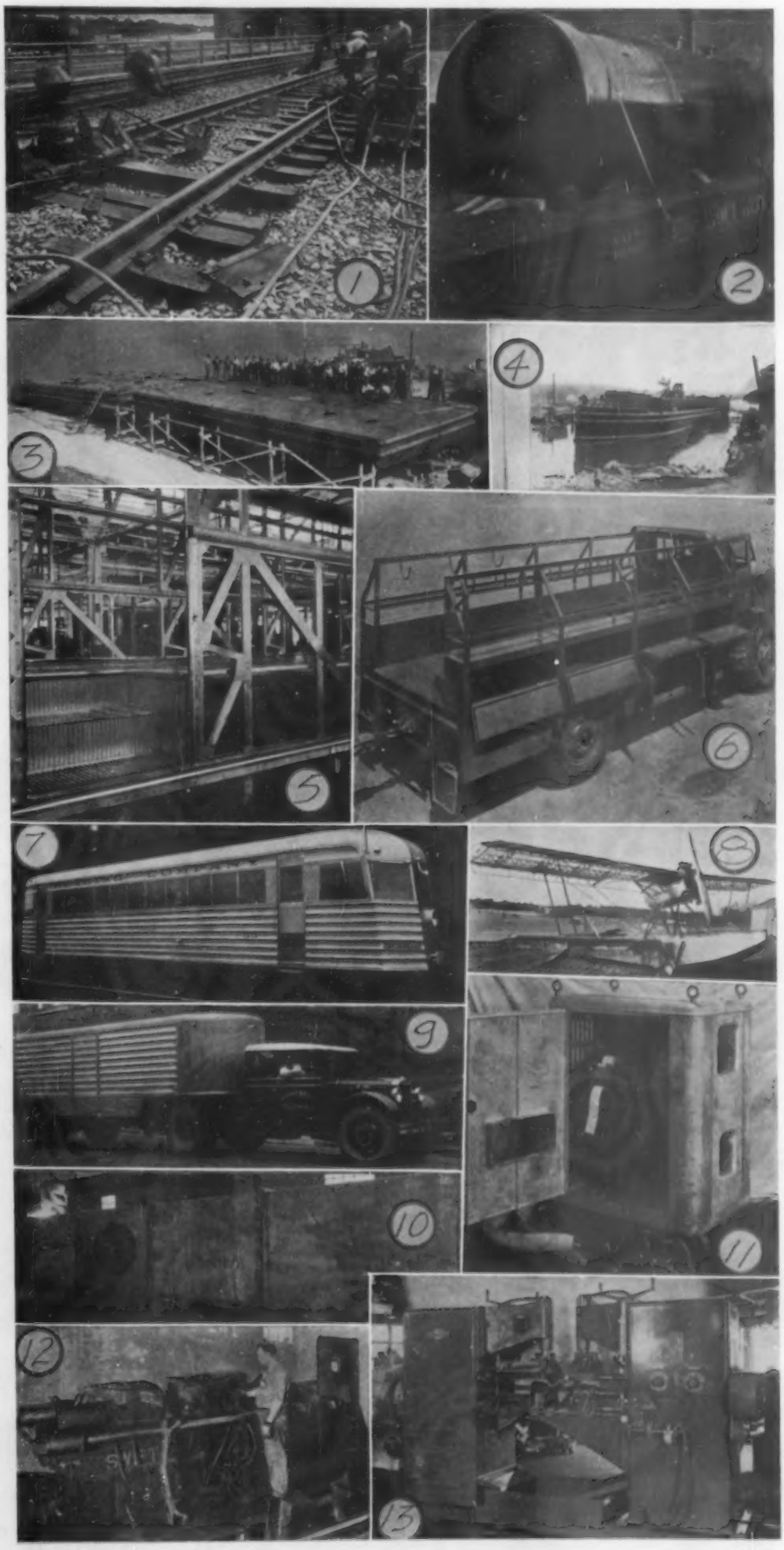
Figure 9 shows a truck body weighing 2000 lb.—a saving of 3000 lb. in dead weight over the conventional. Courtesy E. G. Budd Manufacturing Company.

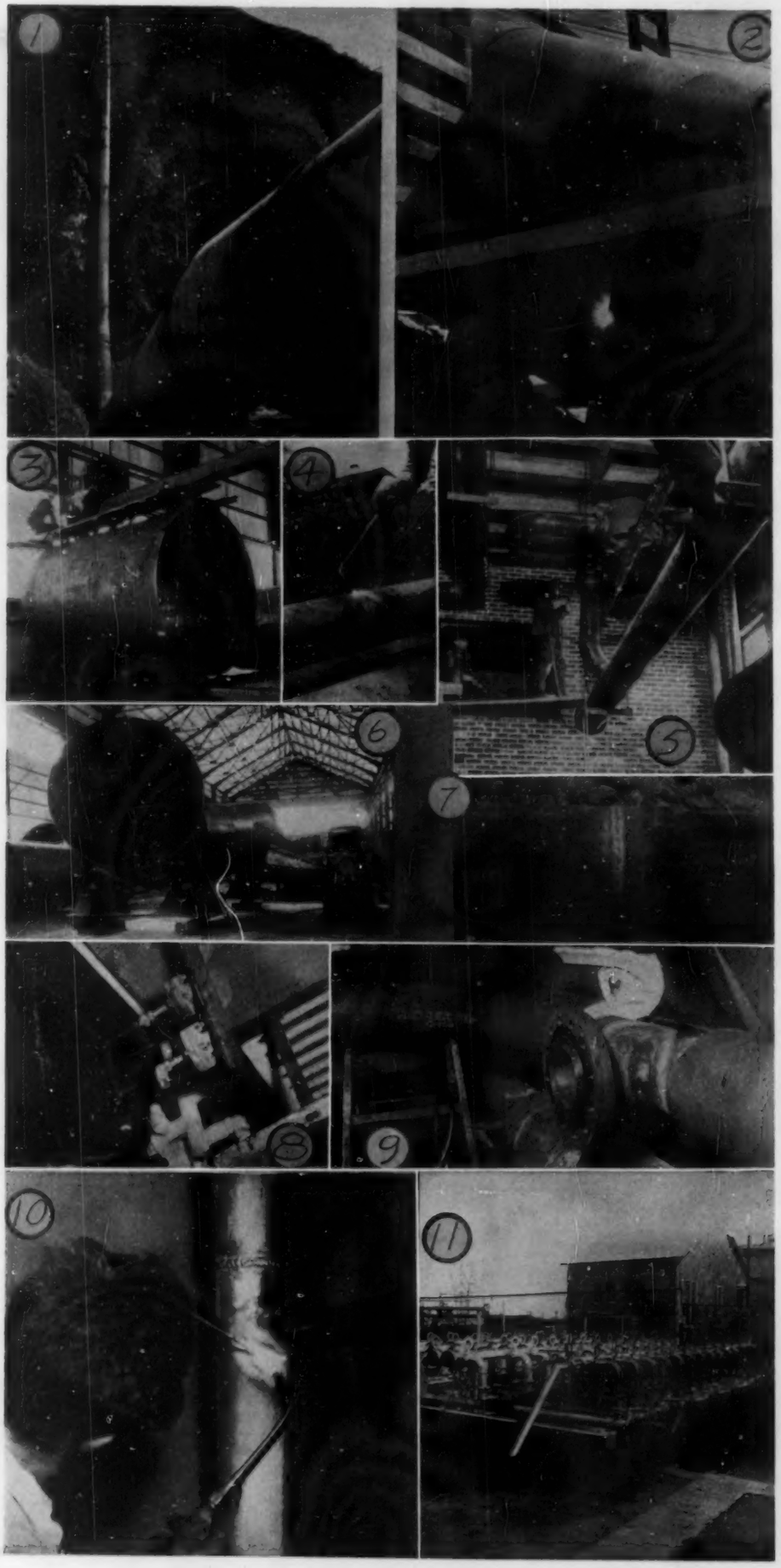
Fig. 10—All-welded wrought-iron smoke duct installed in the roundhouse of the Chicago, Milwaukee and St. Paul Railroad, Chicago, Ill., for which $^3/_{16}$-in. wrought-iron plates were fabricated by the Hansell-Elcock Company, Chicago. Courtesy A. M. Byers Company.

Figure 11 shows Budd 50-kv-a. "Shotweld" machine with the annunciating recorder and its record clearly shown.

Fig. 12—750 kv-a. flash welder, clamps open—work illustrated. The operation is on automobile frame cross members. The members are formed in halves from stock $^1/_8$ in. thick. The length of the part is 39 in. and the weld is 78 in. x $^1/_8$ in., or $9^1/_4$ sq. in. Production is approximately 80 welds per hour. Courtesy Swift Electric Welder Company.

Figure 13 shows machine developed for welding both ends of a hydraulic shock absorber, the body of the absorber being a steel tube and the ends steel forgings. Courtesy Thomson-Gibb Co.





Piping and Pipe-Lines

Conquering canyons and straddling mountains, a $4^1/_2$-mile arc-welded pipe-line will soon join Bouquet Canyon Reservoir with the Owens Valley Aqueduct, near Saugus, California. It varies in diameter from 7 ft. 10 in. to 6 ft. 8 in., depending upon the pressure. The 80-in. pipe is used where the pressure is the greatest. There the pipe is $1^1/_{16}$ in. thick. At the bottom of one of the canyons crossed, the pressure is equal to 400 lb. per sq. in. Fabrication of the pipe is handled by the Western Pipe and Steel Company. See Figs. 1 and 2. Courtesy The Lincoln Electric Company.

Figure 3 shows pipe section, $8^1/_2$ ft. in diam., mounted under an automatic fusion welding machine, in the Field Fabricating Plant of The Babcock & Wilcox Company, at Boulder Dam, for the welding of the longitudinal seam.

Figure 4 shows a rolling weld in an 8-in. pipe-line being made by the oxyacetylene process. Courtesy Air Reduction Company.

Fig. 5—Detail of welded steam piping in a power house. The operator on the scaffold is completing a weld made by the oxyacetylene process. Courtesy Air Reduction Company.

Fig. 6—X-ray equipment and $8^1/_2$ ft. diam. curved pipe section in the Field Fabricating Plant of The Babcock & Wilcox Company at Boulder Dam. Note the method of mounting the sections on rollers so that the seams are readily accessible for X-ray inspection. The X-ray equipment was especially designed for this job by the General Electric Company and will be used to inspect approximately 400,000 lin. ft. of welding on pipe with diameters of $8^1/_2$, 13, 25 and 30 ft. and with thicknesses ranging from $^7/_8$ to $2^3/_4$ in.

Fig. 7—Completed firing line weld on 230 miles of 8-in. oil line for Phillips Petroleum Company from Oklahoma City to Thrall, Kansas. No backing-up ring used. Courtesy H. C. Price, Inc.

Fig. 8—Piping, in breweries particularly, was installed by gas welding, in many cases overnight. And the brewers didn't stop even on small diameter pipe—$^1/_2$, $^3/_4$ and $1^1/_2$ in. pressure piping for both gas and liquid ammonia for air-cooling units was installed with a certainty of giving trouble-free joints. Courtesy Union Carbide Company.

Fig. 9—All the welding on this job was done with the main pipe in position and, as may be seen in the illustration, only a small section of the insulation was removed to install the Weldolet. The fitting was used to connect a 6-in. water regulator line to an existing 8-in. boiler feed line. Courtesy Bonney Forge & Tool Works.

Fig. 10—The gas welding of commercial yellow brass pipe became standard practice during 1933. Courtesy Union Carbide Company.

Fig. 11—Tube-Turns used in valveless manifold by General Petroleum Corporation of California at their Athens, California pipe-line pumping station.

Non-Ferrous Metals

Figure 1 is a 400-barrel brew kettle installed in the Haffenreffer Brewery at Fall River, Massachusetts. It is constructed entirely of Everdur by the Acme Industrial Equipment Company. Courtesy The American Brass Company.

Figure 2 illustrates a vacuum deodorizer 7 ft. 6 in. diam. x 18 ft. long, built entirely of 3S Aluminum $^{7}/_{16}$ in. thick and tested to 60 lb. hydrostatic pressure and 26 in. mercury vacuum. Courtesy Struthers-Wells Company.

Fig. 3—Two welded Inconel tanks, and one nickel water tank, each of 248 gal. capacity, installed in the gin distillery of W. and A. Gilbey, Ltd. Inconel, which contains approximately 80 per cent pure nickel, 12 to 14 per cent chromium and lesser percentages of other elements, can be welded readily without losing its corrosion-resistant properties. Courtesy International Nickel Company.

Approximately 5 tons of ordinary copper were used in fabricating by arc welding three bottom pans, Fig. 4, for rotary mixers to be used in a large food products plant. Courtesy Hobart Brothers.

One of the interesting achievements of modern welding methods is the "Streamline" monel metal sink, Fig. 5. Backsplash, drainboards and apron have each been welded in at least two places, yet the finished product reveals no trace of these operations. Courtesy International Nickel Company.

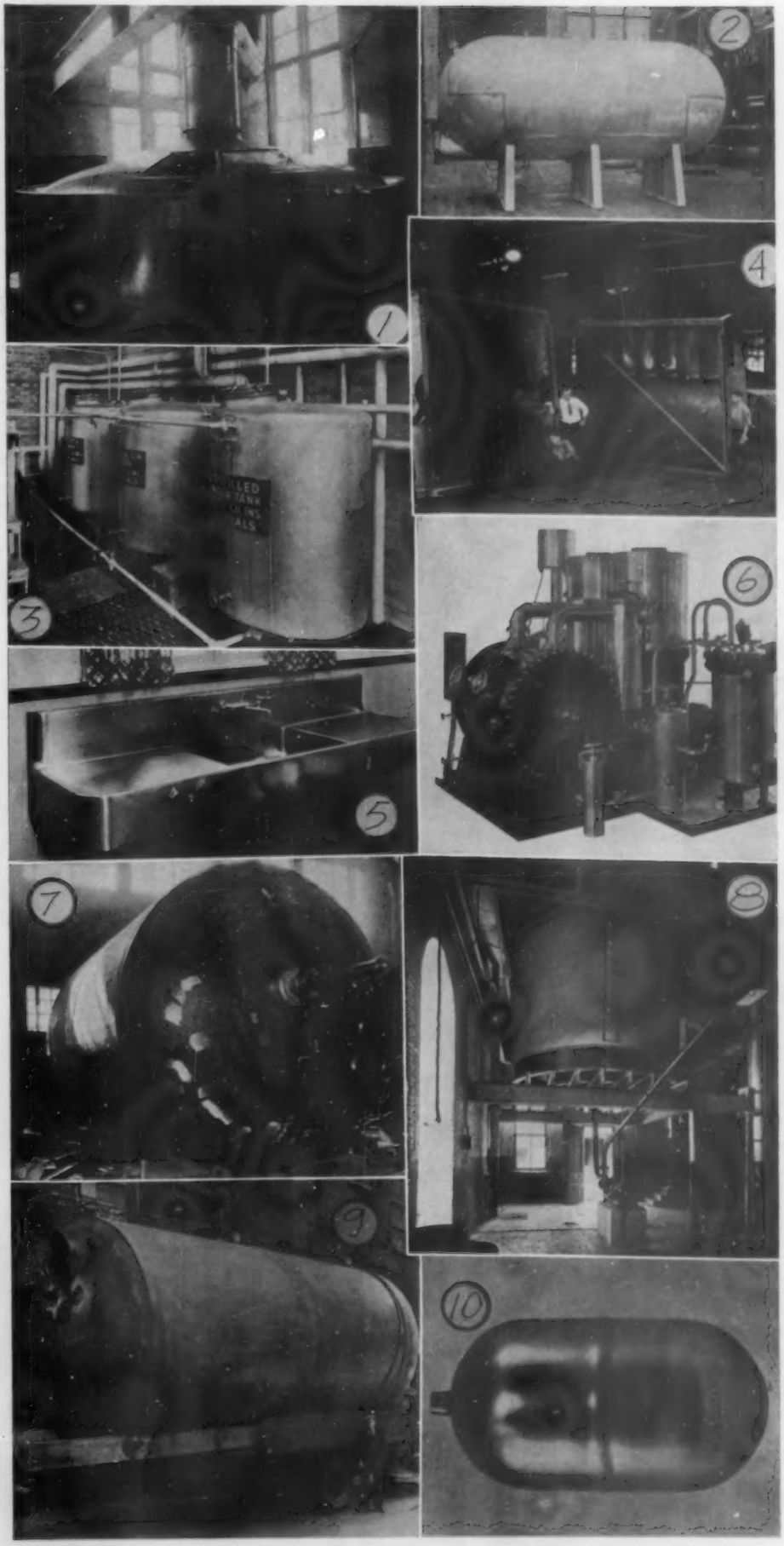
The new non-inflammable dry cleaning systems employing chlorinated hydrocarbon mixtures as solvents are generally constructed of nickel and monel metal. The unit shown, Fig. 6, is an all-nickel job with welded construction throughout. Courtesy International Nickel Company.

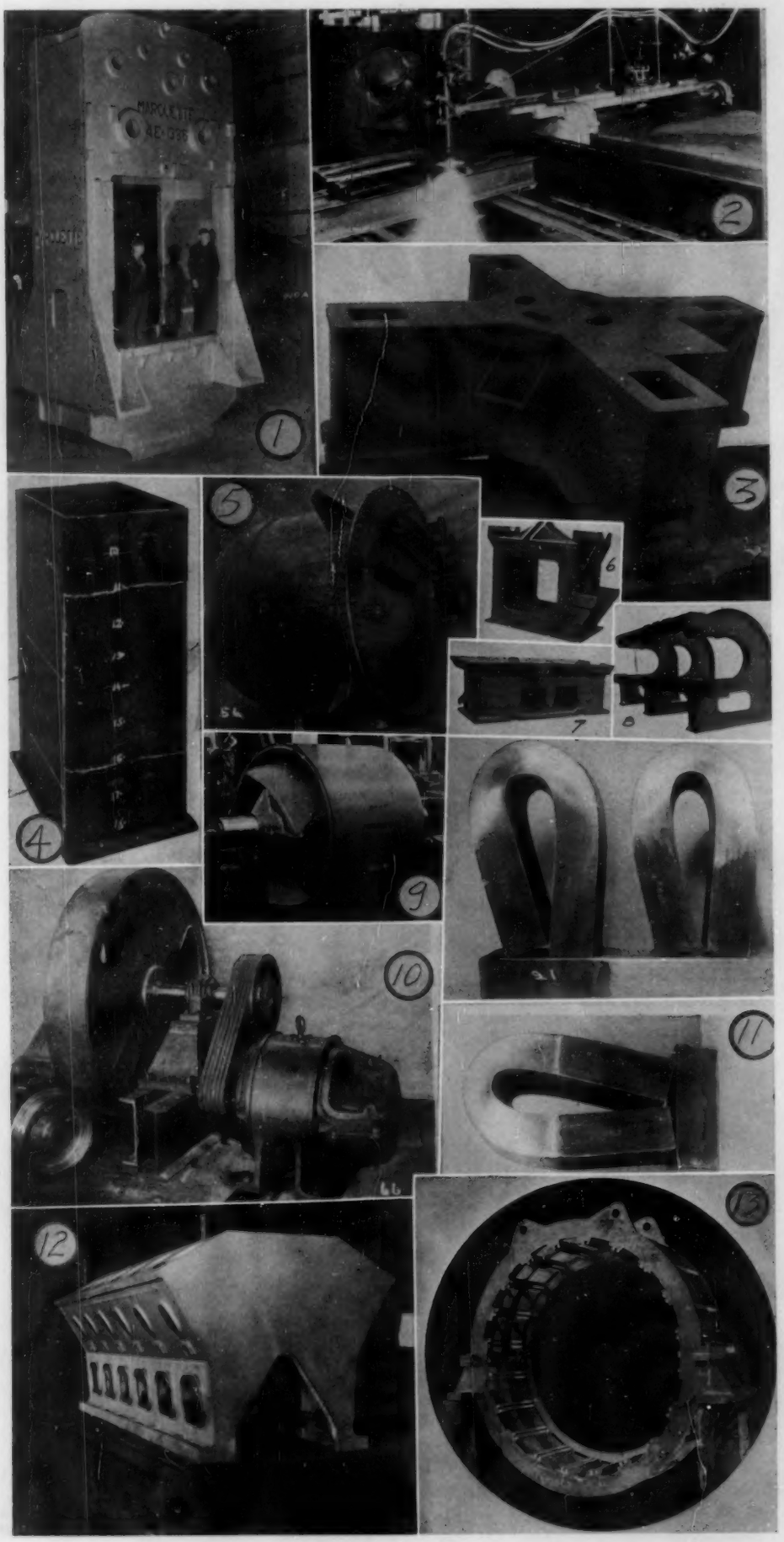
Figure 7 shows Ductil-welded horizontal mash cooker constructed entirely of Everdur metal by the Blaw-Knox Company of Pittsburgh. The inside diameter of this cooker is 11 ft. and the length is 17 ft. 6 in. on the straight shell. The shell is $^{7}/_{16}$ in. thick and the heads are $^{1}/_{2}$ in. thick. Fastened to the shaft on the inside of the cooker are 16 agitator arms. The approximate shipping weight is 20,500 lb. Courtesy The American Brass Company.

Fig. 8—Another 400-barrel brew kettle for a brewery. Courtesy The American Brass Company.

Fig. 9—The use of the oxyacetylene process for the complete fabrication of one of the largest pure copper tanks ever built took place during the past year. The weld produced gave properties fully equivalent to those of the base metal in all respects and permits of subsequent forming and shaping in the welded area with equal facility as in the parent metal. Courtesy Union Carbide Company.

Fig. 10—Monel metal float for high pressure boiler water columns as manufactured by Reliance Gauge Column Company, Cleveland, Ohio. The deep drawing operations by which the upper and lower halves of this float are produced, serve as automatic inspections of flawless perfection, prior to being joined by welding at the middle reinforcing band.





Machinery Construction and Production

Fig. 1—Welded steel frame for mechanical punch press of 1500-ton capacity. Over-all dimensions 22 ft. 6 in. x 11 ft. x 10 ft. Shipping weight 104,360 lb. Courtesy Lukenweld, Inc.

Fig. 2—The accuracy of shape cutting has greatly expanded the use of shape-cut parts. It has enabled economical preparation of heavy thicknesses of steel for fabrication, thereby encouraging its use in fields hitherto closed. Courtesy Union Carbide Company.

Fig. 3—Welded machine base arc welded. Thoroughly annealed before machining. Intricate oil compartments make it an expensive job to cast. Weight, about 6900 lb. Maximum plate thickness, $2^1/_4$ in. Courtesy Wickes Boiler Company.

Fig. 4—Case for telephone loading coils made by the Western Electric Company from $^3/_{16}$-in. copper-bearing fire-box steel. The two vertical welds were made on an automatic seam welder; the bottom was attached by a semi-automatic welder and the lugs were welded by hand.

Fig. 5—Pressure cooker, $5^1/_2$ ft. diam. Accepted arc pressure weld. Courtesy Wickes Boiler Company.

Fig. 6—A rather unusual machine base made of $^5/_8$-in. plates on outside, $^3/_4$-in. plates for center rib, and various thicknesses of fittings up to 6 in. thick. Rounded corners enhance the appearance. Courtesy Whitehead & Kales Co.

Fig. 7—Base with chip pan welded on. This base is watertight for cooling fluid. Over fifty of these have been constructed. Usually $^1/_2$-in. side plates, $^5/_{16}$-in. chip pan, $1^1/_2$ to $2^1/_4$-in. slab top and bottom and $^1/_2$-in. ribs. Courtesy Whitehead & Kales Company. Fig. 8—Frame for machine for grinding weld flash off steel sheets, then annealing them.

Fig. 9—Jacketed Williamson Patented Mill 5 ft. 6 in. diam. x 4 ft. 3 in. long. The special design of head which is of welded plate construction gives the balls a higher lift, increasing the grinding area and reducing the time cycle. Courtesy Struthers-Wells Company.

Fig. 10—Tire testing machine. Flywheel set-up for balancing operation. Weight flywheel alone about 1800 lb., and 5 ft. diam. Balanced at all speeds up to a rim speed of 11,000 ft. per min. All parts of machine built of welded steel construction. Courtesy Wickes Boiler Company.

Fig. 11—Three cold-bend tests required for three drums of a boiler. Boiler plate 2 in. thick. Requirements are 30% elongation on outer fiber. Courtesy Wickes Boiler Company.

Fig. 12—Welded steel frame for 12-cylinder V-type marine Diesel engine 1000 H. P., rough shipping weight, 3125 lb. End view. All members which take the firing load are Cromansil steel. Courtesy Lukenweld Inc.

Fig. 13—Arc-welded frame for a 2812 kv-a., 12,000-volt alternator fabricated by the Crocker Wheeler Electric Manufacturing Company for a Chicago concern. This frame is for one of the largest Diesel-driven alternators in the country. Courtesy Metal & Thermit Corporation.

Pressure Vessels

Fig. 1—50 H. P. A-type boiler, built for 150 lb. W. P. Formerly riveted, now all drums welded. Reduces cost about one-third and increases yearly operating efficiency. Courtesy Wickes Boiler Company.

Figure 2 shows a globe rotary, 15 ft. diam., built for the Southern Extract Company, Knoxville, Tennessee. This rotary is used for cooking chestnut chips after the tannic acid has been removed for making container board. Shell thickness $^{15}/_{16}$ in., working pressure 150 lb. Courtesy Hedges-Walsh-Weidner Co.

Figure 3 illustrates one of two retorts fabricated in the plant of The Steel Tank & Pipe Company and shipped to the Longview Fibre Company.

The retort is 7 ft. in diam. and 80 ft. long. The shell is made of $^{3}/_{4}$-in. plate with $^{5}/_{8}$-in. butt strap at each longitudinal and girth seam; the rear head is made of $^{3}/_{4}$-in. plate flanged and dished from a single plate. Each retort weighs 40 tons and was loaded on 2 freight cars.

Fig. 4—Jacketed mixing tanks 66 in. outside diam. x 48 in. deep between dished heads. Agitator of single motion type, scraping the inside of the kettle with every revolution. Courtesy Struthers-Wells Company.

Fig. 5—Soaking drum 10 ft. inside diam. x 3 in. thick. Shipping weight 309,200 lb. 69 ft. 6 in. over all. Welds made with covered electrodes conforming to A. S. M. E. Class I Vessel. Courtesy The M. W. Kellogg Company.

Fig. 6—12-Foot clay treating tower being X-rayed. Courtesy The M. W. Kellogg Company.

Fig. 7—Fractionating tower arc welded. 14 ft. $8^{1}/_{2}$ in. diam. x 83 ft. 0 in. high, weighing approximately 271,000 lb. when shipped.

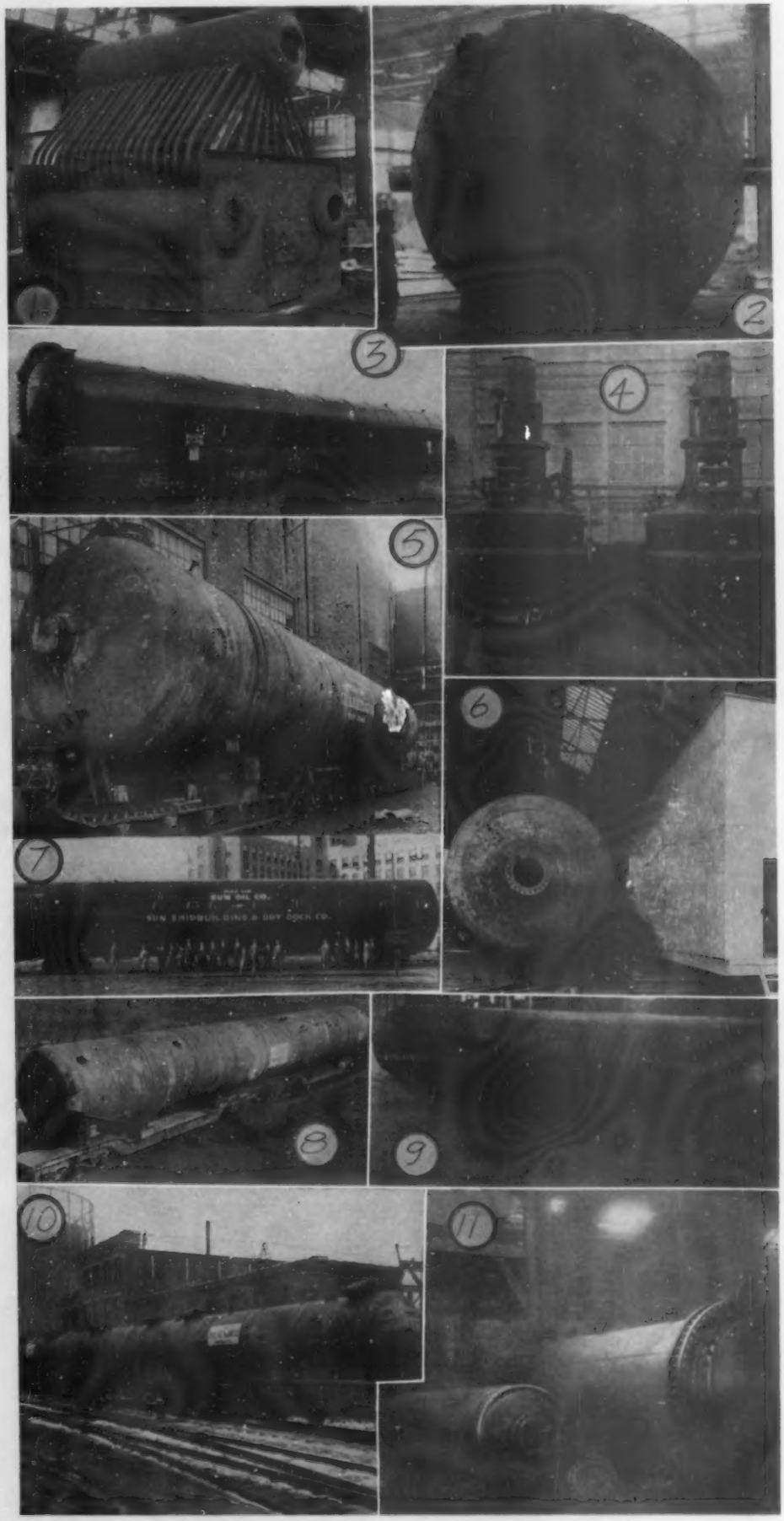
Some of the steel plates which formed the shell were as large as 12 ft. 0 in. wide x $1^{1}/_{4}$ in. x 46 ft. 0 in. long.

Fig. 8—Evaporator and bubble tower made from $1^{3}/_{16}$-in. plate. Tower is 12 ft. inside diam. and 95 ft. long. Shipping weight 254,700 lb. Courtesy The M. W. Kellogg Company.

Fig. 9—One of the twelve fusion-welded drums built for high pressure water tube boilers for the Detroit Edison Company. The drum shown in the photographs is 54 in. I. D. by approximately 30 ft. long, and built for 710 lb. working pressure. The drum shown is made half of 4-in. steel plate and half of $2^{1}/_{2}$-in. steel plate. Other drums were made half of $3^{1}/_{2}$-in. and $2^{1}/_{2}$-in. steel plate. Courtesy Hedges-Walsh-Weidner Company.

Fig. 10—5 ft. 6 in. diam. x 113 ft. long over-all combination bubble tower and evaporator shown loaded for shipment to the steamer dock for export to the Argentine Government Refinery at La Plata. Class 2 fusion-welded construction (electric arc) for 205 lb. and 210 lb. sq. in. working pressure. Weight 127,000 lb. Courtesy The Henry Vogt Machine Company.

Fig. 11—Special boiler Drums. All welded, for 1500 lb. working pressure. 1000-H. P. experimental boiler. Courtesy Wickes Boiler Company.



Impact Values of Weld Metal

By JAMES CAMPBELL HODGE

†Paper presented Monday, October 2, 1933, American Welding Society Fall Meeting, Detroit, Michigan, by James Campbell Hodge, Chief Metallurgist, The Babcock & Wilcox Company.

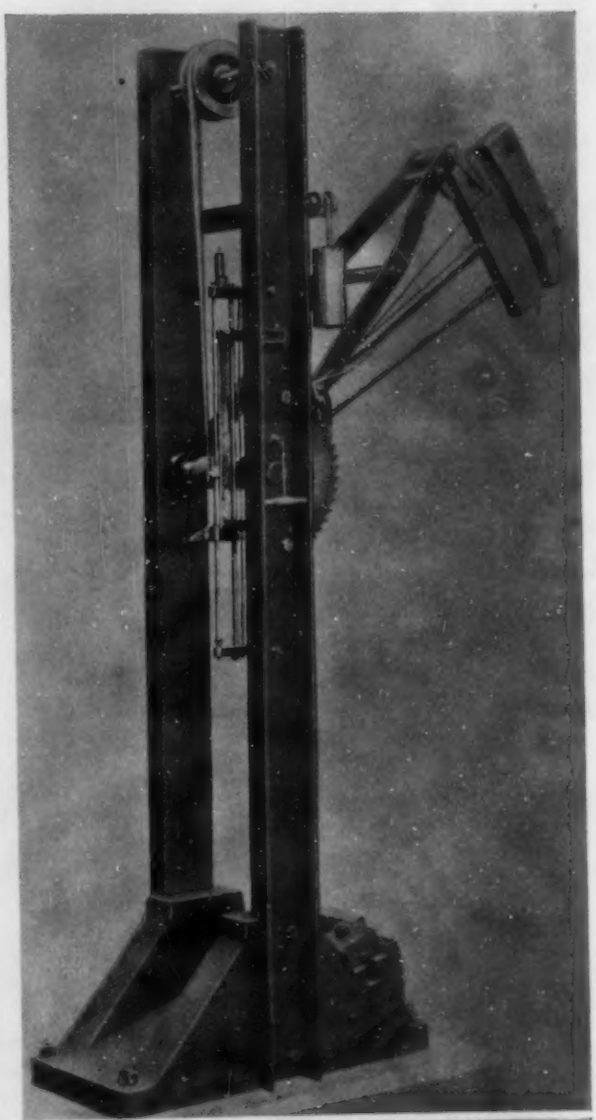
THE basis of mechanical specifications covering the material of a structure or machine is generally the static tensile test, in spite of the general recognition that the properties of tenacity and ductility evaluated by that test can only form a part of the necessary design information to assure satisfaction of the structure or machine in service. The associated property of toughness and lack of toughness, i.e., brittleness, is in general disregarded under the assumption that sufficiently ductile materials are also sufficiently tough. This view point is justified for those materials in which such a correlation has been proved, but is open to question where new materials are introduced into engineering structures or where standard materials are subjected to new service conditions such as the operation of process equipment at low temperatures.

Before proceeding with a presentation of the impact values of weld metals, it is advisable to briefly discuss the impact test and its meaning. The toughness of a metal or alloy is that property which enables it to resist fracture after stressing beyond the elastic range. Fracture in a tough metal will not occur until it has been subjected to considerable deformation. Brittleness is the antithesis of toughness and has been defined as the ease with which a metal breaks after the elastic limit has been passed. In brittle metals the deformation on stressing beyond the elastic range is quite limited, and in a very brittle material the elastic limit and the ultimate tensile strength are of the same value. More specifically, brittleness is the property of fracturing suddenly when subjected to sudden application of stress such as impact blows, and the various impact test values are usually taken as a measure of the brittleness or toughness of a metal.

In the impact test a weight is permitted to fall through a measured height on a specimen of the metal to be tested, and the test value obtained is the work absorbed by the fracturing of the specimen. The specimen in the impact test is notched and is so supported in the impact testing machine that the blow from the falling weight, usually a swinging pendulum (Fig. 1), is concentrated behind the notch. Two types of impact specimens and testing machines, known as the Izod and Charpy (Fig. 2), are extensively used in this country. Each type of specimen has its advantages and disadvantages; the impact values reported in this paper are Charpy values.

The property of toughness or brittleness is related to the properties of hardness, tenacity and ductility, particularly the latter. We should expect to find great toughness associated with high ductility and low hardness and an extremely brittle condition associated with great hardness and low ductility. These relationships between these properties are only generally found, and the fact that exceptions are quite common may be proved by ex-

Fig. 1—Impact Testing Machine of Swinging Pendulum Type (Charpy Model)



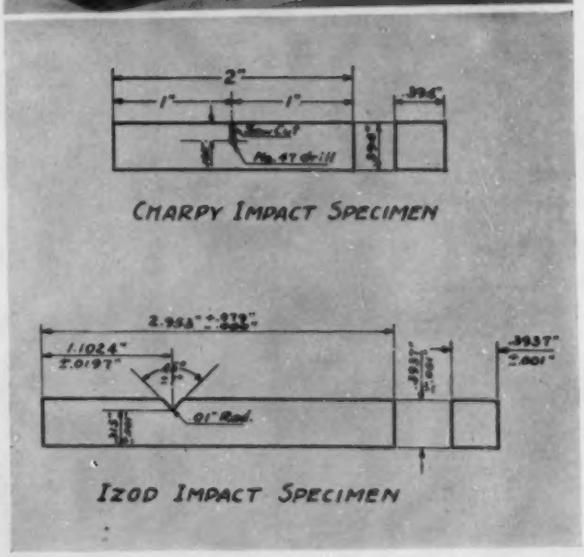


Fig. 2—Dimensions of Standard Charpy and Izod Notched Impact Specimens

Table 1—Effect of Temperature on the Tensile and Impact Properties of a 0.21% Carbon Steel (Boiler Plate 0.45% Mn, 0.02% Si)

Degrees fahr.	−112°	−50°	0°	70°	300°	600°	900°
Yield point, lb./sq. in.	42,000	36,000	33,000	30,000	29,250	30,500	
Tensile str., lb./sq. in.	61,000	58,500	56,750	55,000	60,200	69,000	50,000
Elong. in 2 in., per cent	40.0	37.0	42.0	40.0	34.5	21.5	42.0
Reduc. of area, per cent	59.8	56.0	50.0	55.0	55.9	51.0	62.0
Charpy impact, ft.-lb.	1.5	1.5	4.0	28.0	27.0	22.5	15.7

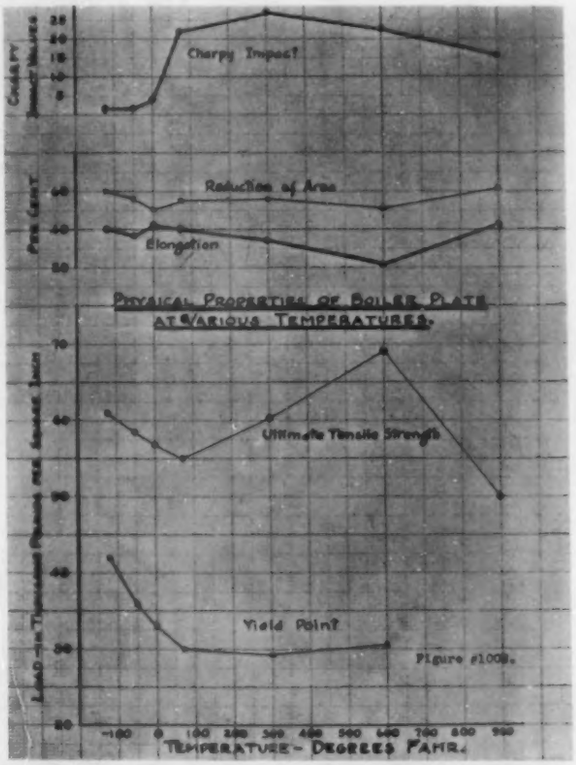


Fig. 3—Effect of Temperature on the Static Tensile and Notched Impact Properties of Boiler Plate, Showing That Notched Impact Value Is Not Necessarily Related to Ductility Values

amination of the properties of plain carbon steel throughout a range of temperature (Table 1).

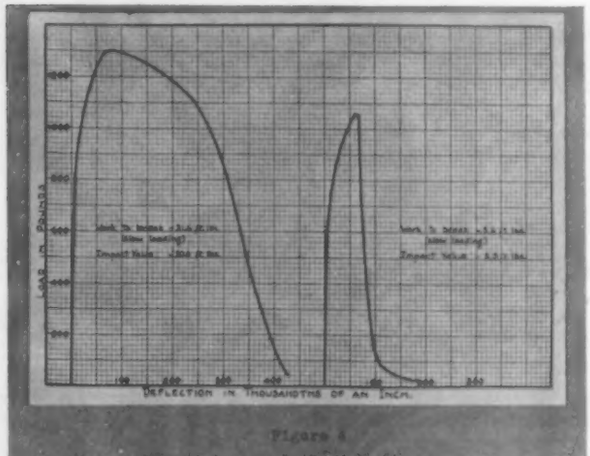
It should be noted that the effect of temperature upon the impact value of the steel is disproportionate to the effect of temperature upon the static tensile properties of the steel. For example, the ductility is little affected by drop in temperature from normal temperature to −112° F., whereas the impact value in the low temperature range is but a fraction of the normal temperature value.

Since high ductility does not necessarily imply high toughness or high impact resistance, it is necessary to arrive at a satisfactory understanding of the meaning of impact test values. The first striking, although generally unrecognized, feature of the impact test is that the amount of work absorbed in fracturing an impact specimen is independent of the speed of testing or application of the load. This applies to specimens of either high or low impact resistance, as shown in Fig. 4. The stress-strain diagrams represent the testing to fracture of a relatively tough and relatively brittle material under slow static loading, and the work performed in fracturing each specimen as represented by the area within the diagram as exactly the same as the work absorbed by fracturing similar specimens by sudden blows as in the impact test. (The two diagrams of Fig. 4 represent two steels of the same tensile properties.) The values obtained in impact testing are, therefore, independent of the speed of testing or the striking velocity of the hammer of the testing machine.

It has been suggested that the term impact value be replaced by the term notched bar value as more descriptive of the nature of the test. The graphical representation of the two types of fracturing of the notched impact specimens of the two metals which have otherwise identical physical properties throws some light on the nature of this test. In the relatively tough material (31.6 ft.-lb.) a large amount of work is absorbed after the maximum load has been applied. This work has been expended in distortion of the metal in the region of the notch simultaneously with the development and extension of the fracture through the specimen. In the relatively brittle material (5.5 ft.-lb.) the work absorbed after the maximum load is negligible, indicating little distortion of the metal in the region of the notch and easy development and propagation of the fracture.

The notched impact value may, therefore, be con-

Fig. 4—Stress-Strain Diagrams of Two Notched Impact Specimens, Fractured Slowly of (1) a Relatively Tough Steel and (2) a Relatively Brittle Steel. Total Work Absorbed in Fracturing Is in Each Case Equal to Work Absorbed under Impact Loading



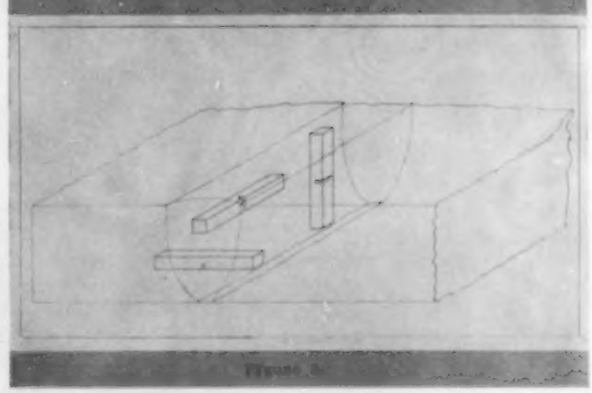


Fig. 5—Locations of Specimens in Welded Joint: (a) Horizontal Transverse, (b) Horizontal Longitudinal and (c) Vertical

sidered as a measure of the ability of a metal to resist the development and spread of a fracture, due to the application of a single large stress concentrated over a small area.

Bearing in mind the above significance of the impact or notched impact test we may now proceed to a presentation of the notched impact values of weld metals.

Weld metals are comparatively recent additions to engineering materials and, although essentially low-carbon steels, their toughness or brittleness cannot be predicted from the general behavior of standard low-carbon steels. This is due to the extremely abnormal conditions of melting temperature, casting and heat treatment under which weld metals are produced, with resultant composition and structure peculiar to those conditions, which differ entirely from normal melting, thermal and mechanical treatments of commercial steels. It is also apparent that the toughness of a weld metal will be largely dependent upon the special process of arc welding employed and the variables attendant to any form of arc welding, such as type of electrode, type of joint, location of test coupon within the weld, etc.

It should be expected that the impact resistance of single bead weld metal, possessing a coarse columnar structure, be lower than that of multiple layer weld metal, in which grain refinement has occurred. The difference is of the order of 6 ft.-lb. for single bead weld metal and 33 ft.-lb. for multiple layer weld metal. (Values from metal arc weld metal deposited from hydrogen protected arc.) All notched impact values of weld metals of this paper were obtained from multiple bead welds on plate thicknesses of 1 in. and over. In rolled and forged steels the impact value is affected by the position of the notch in the test specimen with respect to the direction of working of the steel, and the impact value of weld metals should be dependent upon the relationship of the notch with respect to the direction of the original columnar grains of the weld metal. Figure 5 shows three positions of impact specimens as related to a welded joint: (1) HT . . . coupons are horizontal and are transverse to the welded joint, (2) HL . . . coupons are horizontal and are longitudinal or parallel to the axis of the weld, (3) V . . . coupons are vertical within the weld. The average of four specimens of each type from a weld metal of the covered electrode type are as follows:

Horizontal transverse	33.4 ft.-lb.
Horizontal longitudinal	31.2 "
Vertical	38.5 "

The HT and HL types give about the same values, while the impact value of the vertical type is considerably higher due to the fact that in this type the fracture must extend across the original columnar crystals of the weld layers. All notched impact values reported were obtained on specimens of the horizontal transverse type.

Notched Impact Values of Weld Metals of Different Welding Processes

Table 2 gives the room temperature impact values of various types of weld metals. The bare electrode metal arc welds are subject to wide variations, even in the same weld, and the notched impact values indicate an unreliable brittle metal. The covered electrode metal arc weld metals possess relatively high impact values, comparable with the average values obtainable on rolled plain carbon steels such as boiler plate. In fact the minimum values obtained on a very large number of covered electrode welds are much higher than the minimum values obtained on boiler plate. The notched impact values obtained on the carbon arc weld are fair. The weld metals of this

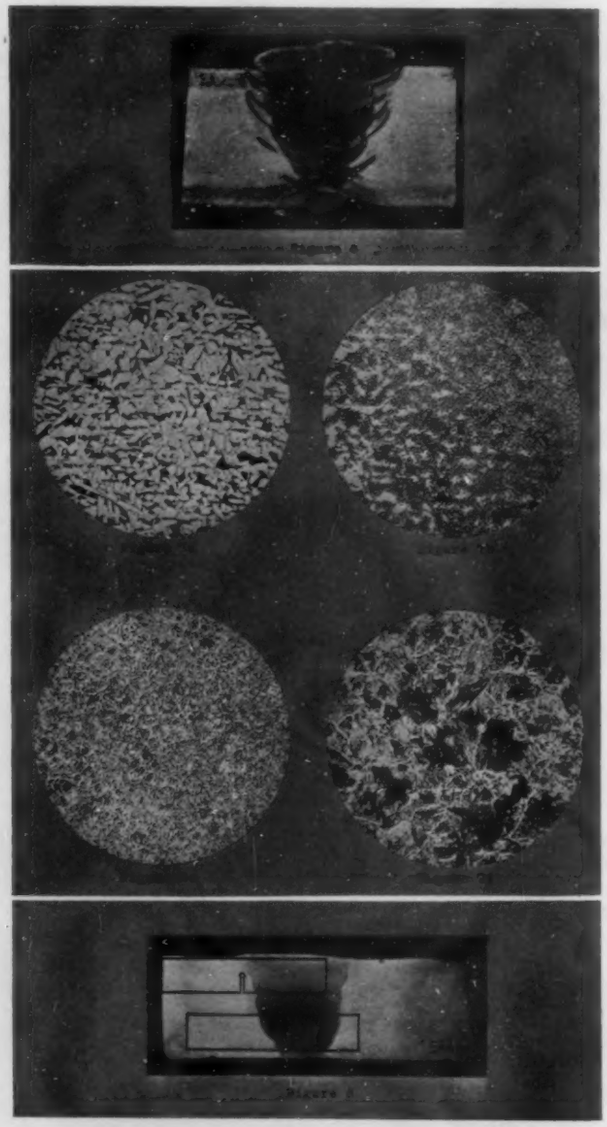


Fig. 6—Macrograph of Section across Welded Joint (2 In. Thick Plate) Showing Affected Zone of Parent Metal

Fig. 7(*a*)—Original Structure of Unaffected Boiler Plate (100×, Etchant 4% Nital)

Fig. 7(*b*)—Affected Zone Adjacent to Unaffected Plate (100×, Etchant 4% Nital)

Fig. 7(*c*)—Fine-Grained Structure of Affected Zone Near Line of Fusion. This Structure Typifies Bulk of Affected Zone (100×, Etchant 4% Nital)

Fig. 7(*d*)—Sorbitic Structure of Affected Zone Near Line of Fusion. Present Only in Extremely Small Quantities

Fig. 8—Method of Studying the Relative Toughness of the Original Plate, the Various Parts of the Affected Zone, the Fusion Zone and the Weld Metal

Table 2—Impact Values of Various Types of Weld Metals

Process	Location of Specimen Top	Middle	Bottom
Bare electrode—Weld 1	1.0	2.0	3.0
Bare electrode—Weld 2	1.0	..	1.5
Bare electrode—Weld 3	13.0	5.0	10.0
Bare electrode—Weld 4	7.5	..	9.0
Bare electrode—Weld 5	6.5	..	15.0
Covered electrode—Weld 1	18.0	18.0	25.0
Covered electrode—Weld 2	33.0	28.0	31.0
Covered electrode—Weld 3	25.0	25.0	20.0
Carbon arc weld	13.0	15.0	23.0
Protected arc—Weld 1	29.0	33.0	35.0
Protected arc—Weld 2	26.0	42.0	37.0
Boiler plate—as-rolled	Min. 19.0 ft.-lb. Max. 33.0 ft.-lb.		

process will show widely varying impact values due to irregular absorption of carbon by the molten weld metal from the carbon arc and due to wide variations in the grain structure of the metal. The impact values of the hydrogen protected metal arc welds are excellent.

A warning should again be sounded as to interpretation of the above data. It may be assumed that all bare electrode metal arc weld metals are more or less brittle; on the other hand, the assumption cannot be made that all covered electrode metal arc welds are tough, as the quality of such welds is dependent upon a number of variables, nature of the covering, length of arc, bead deposition, etc.

Correlation of the impact values presented with the conditions surrounding the molten weld metal of each welding process will show that high notched impact values are obtained on weld metals deposited under reducing conditions around the arc, or under conditions in which the molten metal is protected from the oxidizing and nitrogenizing action of the atmosphere. This condition has been described in an earlier paper.[1]

Notched Impact Values of the Affected Zone of the Parent Metal

Examination of the macrograph of a section across a welded joint (Fig. 6) will show that the parent metal is differentially etched for a depth of $^3/_{16}$ in. from the line of fusion between weld metal and plate, this differentially etched zone corresponding to that portion of the plate material in which the original grain structure has been altered by the heat of the weld metal. Micro examination of this affected zone will show various microstructures ranging from the original pearlitic structure of the plate, through an extremely fine-grained microstructure to a coarse sorbitic structure (Fig. 7). In single bead deposition the bulk of the affected zone will be of coarse sorbitic structure while in multiple bead deposition the bulk of the affected zone will be extremely fine grained with the coarse sorbitic structure present only in extremely small quantities.

To determine the impact values of the affected zone of the plate material of a weld, impact specimens were removed from eight different sections of two different welded samples in marine boiler plate, the location of the notch of the individual specimens being varied as shown in Fig. 8. Table 3 gives the impact values of different portions of a weld.

The data of Table 3 indicate that excellent impact properties prevail throughout all zones of a weld and that the presence of coarse sorbitic structures does not reduce the impact values of the affected zone. In fact tests of plate material heat treated to produce coarse-grained structures such as exist in small amount and at scattered points in the affected zone of the plate material of a welded seam show excellent tensile and impact values.

Notched Impact Values of Weld Metals at High Temperatures

In comparing the static and dynamic tests of steels at various temperatures, Robin[2] early pointed out that "The properties of steel, so far as the dynamic and static effects are concerned, vary in totally different ways according to the temperature and according to the nature of the steels. Brittleness as the result of static effects appears to occur at 300° C. (570° F.), but brittleness under shock is practically in the neighborhood of 500° C. (930° F.)."

[1] "Chemistry of Low-Carbon Metal-Arc Weld Metals," J. C. Hodge, A. W. S., October 1932.

[2] Robin, "The Resistance of Steels to Crushing Temperatures," Carnegie Scholarships Memoirs, Vol. 2, page 70.

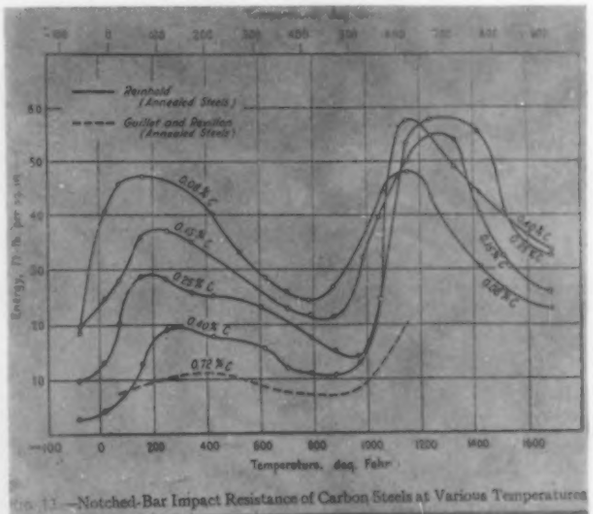


Fig. 9—Notched-Bar Impact Resistance of Carbon Steels at Various Temperatures

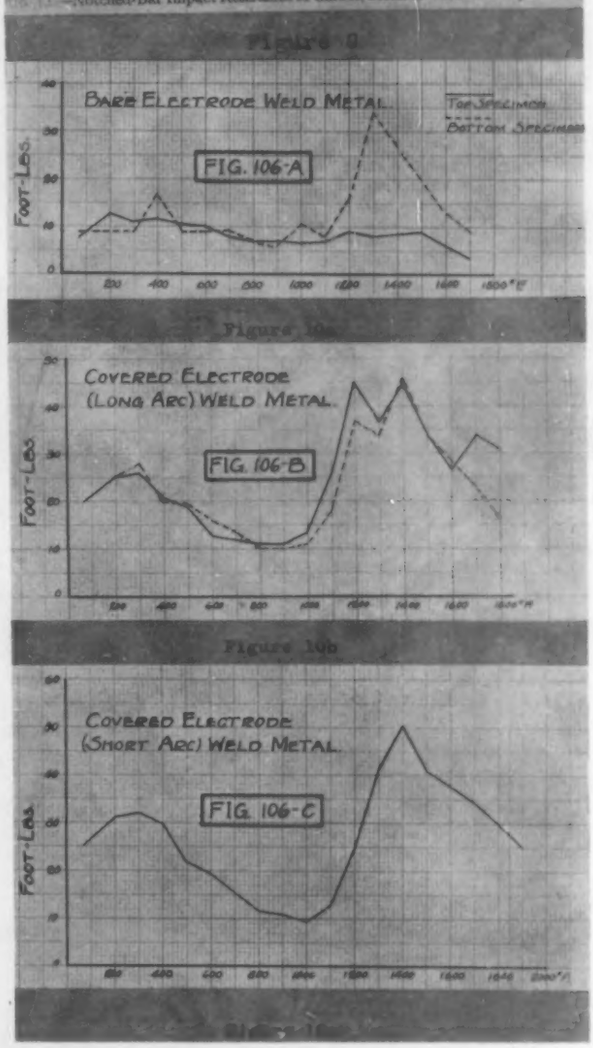


Fig. 10—Notched-Bar Impact Resistance of Three Welds at Elevated Temperatures

The notched-bar impact resistance of several carbon steels[3] at various temperatures is given in Fig. 9. The general form of the impact energy-temperature curves

[3] From paper by French and Tucker "Available Data on the Properties of Irons and Steels at Various Temperatures."

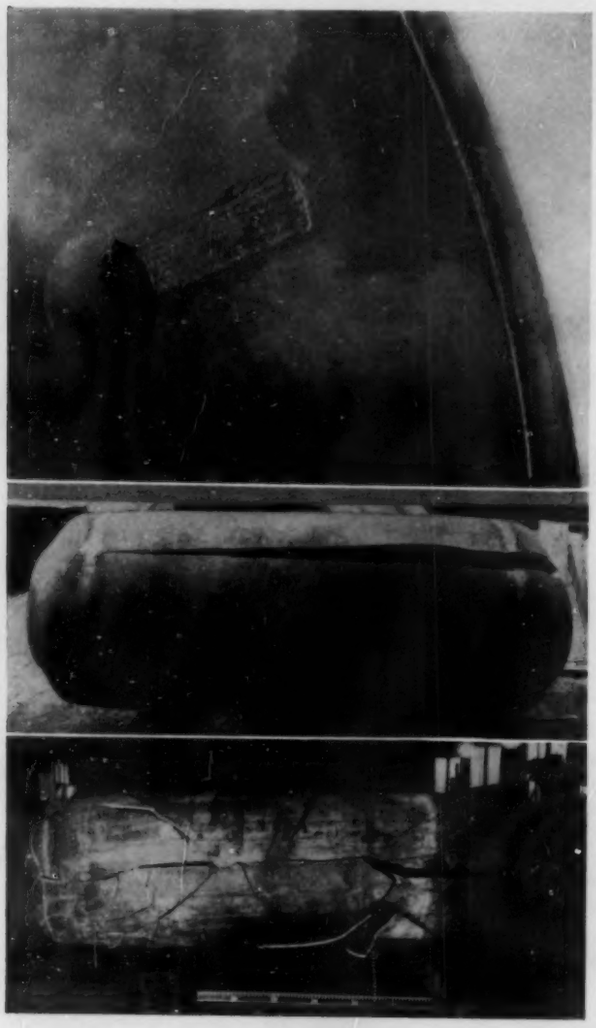


Fig. 11 (Upper)—Showing High Velocity Fracture Which Developed through Unrelieved Stress Repair Weld

Fig. 12 (Center)—Showing Failed Welded Test Drum with Simple Longitudinal Fracture through Boiler Plate of Normally High Notched Impact Value

Fig. 13 (Lower).—Showing Failed Welded Test Drum (Hydrostatic Destructive Test) with Plate Material Shattered Due to Low Notched Impact Value of Plate Material

is quite similar for the majority of steels tested, the absorbed energy being maximum in the region of 150 to 400° F., after which it decreases to a minimum in the neighborhood of 800 to 1000° F., and is then followed by a sharp rise as the temperature reaches the plastic range of the steels.

Figure 10 shows the impact energy-temperature relationships of three types of weld metals: Type 1 . . . bare electrode weld metal; Type 2 . . . covered electrode (long arc) weld metal; and Type 3 . . . covered electrode (short arc) weld metal. (See Reference 1 for chemical analysis). The impact energy-temperature curves for the three weld metals are similar to the general form of the curves for the low-carbon rolled steels of Fig. 9, the differences being of magnitude only. Maximum brittleness in all three welds occurs between 800 and 1000° F. Both covered electrode welds are superior to the bare electrode weld metal throughout the entire temperature range. The differences, however, between the three types of weld metals in the range of maximum brittleness are not as marked as might have been expected.

Table 3—Impact Values of Different Portions of Welds (Covered Electrode Metal Arc Type)

Location with Respect to Thickness of Plate	Location with Respect to Width of Affected Zone	1¼ In. Thick Plate, Ft.-Lb.
Middle	Line of fusion	20.0
Middle	Line of fusion	21.5
Middle	Line of fusion	22.5
Middle	Line of fusion	22.5
Middle	Affected zone—center	31.5
Middle	Affected zone—center	34.5
Top	Affected zone—center	29.0
Bottom	Affected zone—center	27.5
Top	Affected zone adjacent to normal plate structure	27.0
Middle	Affected zone adjacent to normal plate structure	27.5
Middle	Affected zone adjacent to normal plate structure	24.5
Middle	Affected zone adjacent to normal plate structure	28.0
Top	Affected zone adjacent to normal plate structure	33.0
Bottom	Affected zone adjacent to normal plate structure	31.0
Weld metal—center		22.0
Weld metal—center		22.0

Effect of Heat Treatment upon the Impact Resistance of Weld Metals

Due to the abnormally high nitrogen contents of weld metals and to their peculiar grain structures, it should be expected that the physical properties of weld metals should be susceptible to various heat treatments. This is unquestionably true for the static tensile and hardness properties of the weld metals but apparently the notched impact values of weld metals are independent of the usual heat treatments from above the critical range. At least no general trend can be drawn from the experimental results obtained by the writer.

For example, no great variation existed in the notched impact values of specimens of a covered electrode weld metal, after water quenching from temperatures at 100° F. intervals throughout the range of 200 to 1700° F. This is probably due to the practical absence of nitrides of this weld metal and to the practical absence of the effect of this constituent on quenching the weld metal. Unfortunately this research was not conducted on bare electrode weld metal, where the effect of the much higher nitrogen content should have been pronounced.

Similarly the effect of annealing from above the critical temperature of the weld metal is inappreciable as shown by the data of Table 4. The last two treatments were sufficient for complete recrystallization of the weld metals, and complete equi-axing of any residual coarse columnar structure occurred. There is a slight tendency toward higher values for the covered electrode weld metal after complete annealing.

In case it be construed from the fact that the impact value of a weld metal in the as-welded condition is approximately the same as that of the weld metal after stress-relieving, that welded joints in the as-welded condition possess a satisfactory resistance to impact, it should be pointed out that the notched impact value is obtained on a small specimen cut from the welded joint. The mere cutting of such a small specimen from a welded joint without stress-relieving frees the metal of the specimen from the large elastic stresses existing within the welded joint. A practical demonstration of the above relationship between high notched impact values obtained on small impact test specimens and the low impact resistance of a welded joint without stress-relieving is

Table 4—Effect of Heat Treatment upon the Notched Impact Values of Weld Metals

	Bare Electrode, Weld Metal 1	Bare Electrode, Weld Metal 2	Covered Electrode, Weld Metal
As-welded	4.5	5.5	23.0
Stress-relieved, 1200° F.	6.5	7.5	22.5
Annealed 1750° F., 1 hour	3.0	6.0	27.5
2100° F., air cooled 1750° F., air cooled	7.0	9.7	29.0

given in Fig. 11, in which a high velocity fracture developed in an unrelieved stress repair weld and extended from the edge of a nozzle hole to the end of the plate of the shell in a fatigue test drum similar to the series tested and described in earlier papers.[4]

Relationship of Notched Impact Value to Engineering Design

It is somewhat difficult to interpret notched impact values of a material from the view point of the service condition of the material in a structure or machine. It is certain that the notched impact value should only be considered along with the other static and dynamic properties of a material. If we accept the interpretation of the notched impact value as described in the early part of this paper, namely, as the resistance of a metal to the spread of a fracture, the values obtained are of obvious importance.

In the fatigue tests of full-sized welded shells previously referred to, the fatigue cracks which developed in covered electrode weld metal of high notch impact value propagated very slowly. On the other hand, in the fatigue test shell with welded joints of bare electrode weld metal with low notched impact value, a fatigue crack developed after a relatively small number of applications of pressure as evidenced by a slight leak through the welded joint. When the test pressure was again applied to this shell this fatigue fracture spread suddenly along the length of the joint.

Further practical evidence as to the correctness of the above interpretation of the notched bar value is given by comparison of the type of failures resulting in hydrostatic tests in the two welded drums of Figs. 12 and 13. The plate material of the first drum when the drum was tested to destruction possessed the normal relatively high notched-bar value of boiler plate, whereas the plate material of the second drum due to an age hardening effect, description of which will not be incorporated here, possessed an extremely low impact value. The difference in the nature of the fractures which developed in the two drums is obvious. The simple longitudinal failure of the tough boiler plate material is in marked contrast to the shattering of the brittle plate material of low notched impact value. It is quite evident that the plate material of the test drum in Fig. 13 possessed low resistance to the spread of the fracture which must have developed at some local point at the moment of bursting of the drum. The latter illustration is, of course, drawn from structures tested to destruction, where the maximum stress is the same as the ultimate tensile strength of the material. The illustration drawn from fatigue tests, however, of the development of the fracture in the brittle weld metal and the tough weld metal is applicable to stresses normally encountered in many engineering structures.

In closing it should again be stated that the impact values presented in this paper represent only those of weld metals made and deposited under the conditions described. They apply only to low-carbon weld metals joining carbon steels within the range of carbon contents 0.15 to 0.35%.

[4] "Tests of the Resistance to Repeated Pressure of Forged, Riveted and Welded Boiler Shells," H. F. Moore and "The Application of Fusion Welding o Pressure Vessels," J. C. Hodge.

Data on YF-221

By **P. B. DUNGAN**

†Paper presented at Feb. 16, 1933 Meeting, Los Angeles Section, A. W. S., by P. B. Dungan, Captain U. S. Navy.

IN THE building of this craft the order of erection on the building ways was as follows: (1) keel; (2) bottom shell; (3) bottom longitudinals; (4) stem and sternposts; (5) rider plate; (6) transverse web frames and bulkheads; (7) side longitudinals; (8) side shell; (9) sheer strake; (10) deck stringer; (11) chain locker flat; (12) bulwarks; (13) miscellaneous items such as shaft tubes, struts, foundations, deck plates, deck house, etc., in natural and convenient order.

The general conception of the structure for the purpose of welding is that of an envelope or diaphragm of plating stretched over a rigid interior framework. The envelope of plating is composed of the shell and the deck plating. The rigid interior framework consists of the longitudinal members including longitudinals, deck beams and stringers, and the transverse members including web frames and bulkheads.

The general procedure was first to connect the interior framework together to form a rigid structure. At the same time the shell was connected together to form a complete envelope. The envelope of plating was then connected together to form a complete envelope. The envelope of plating was then connected to the interior framework to form the completed hull of the ship.

In connecting the interior framework together, the first step was to weld the butts of all continuous longitudinal members, starting from amidships and working fore and aft. The deck stringer was treated as a continuous longitudinal member because it furnished the principal longitudinal strength for the upper flange of the ship girder. All longitudinal members were next welded to transverse members, starting amidships and working in complete transverse rings with a welder on either side of the center line of the ship.

In connecting the exterior envelope of shell plating together, the butts of the shell plating were welded first, starting from amidships and working fore and aft. No butt was welded unless three sides of the plate were free to move. The word "plate" here may be interpreted broadly as meaning several plates welded together, provided all are free to move, that is, bolted loosely with

bolts smaller than the holes or tack welded by small tacks incapable of resisting the shrinkage stresses. In this manner the shrinkage of the butts was unrestrained. The shell seams were next welded, and no seam generally was welded unless two sides of the plate (one side and one end) were free to move.

Longitudinal members were next welded to the shell plating, starting amidships and working fore and aft. This was followed by transverse members of the framework such as bulkheads or transverse frames next being welded to the outside plating, starting amidships and working fore and aft.

The main deck stringer was considered as a continuous longitudinal member as explained above. The remainder of the main deck, however, was welded together following the principle laid down above for butts and seams of shell plating. After this welding of the main deck was complete and the deck had contracted as much as was required, it was connected along its boundary to the deck stringer. In this last connection the shrinkage of the deck plating was restrained, and for this reason the welders were required to skip about freely so as to avoid any local concentration of heat.

In practically all the work on this vessel, flat, vertical and overhead, heavily coated, fluxed electrodes were used because of the superior strength and elasticity of the weld metal.

In practically all this work the welders were required to work in pairs so that the welding progressed equally on the port and starboard sides, making whatever shrinkage resulting therefrom symmetrical about the center line. Shrinkage is caused by concentration of heat and can be minimized by avoiding too great a local concentration. This is accomplished by using the "wandering method," that is, welding 3 in. and skipping from 18 to 24 in., returning later to fill in the intervals between. Piece-work welders have been required to skip about as were day welders. It was customary to do most of the tacking in the daytime when the ship-fitting trades were working and the supervision was most favorable. The night gangs of electric welders would finish the welding of the material tacked in the daytime.

Welding Equipment

Every linear foot of welding in the shop and on the ship was performed by the electric arc method. The best and most up-to-date portable single and multiple operator machines were employed in the welding of the ship and on the fabricated frames and parts in the shop.

For the protection of the welders from burns, leather aprons and armlets were issued to the welders. This protection is necessary to all welders when flux-covered electrodes are used in the vertical and overhead positions.

Welding Rods and Current

This lighter was welded entirely with flux-covered electrodes and is the first all-welded ship welded entirely with these rods. The chemical composition of these rods was as follows: 0.11 carbon, 0.47 manganese, 0.013 phosphorus, 0.021 sulphur, 0.13 silicon.

The physical characteristics of the deposited metal were as follow:

Average 68,750 lb. per sq. in. T.S.
Average 24.5% elongation in 2 in.
Average 7.81 specific gravity

Deposit efficiency of the electrodes used, figured on a basis of 100 lb. of electrodes, is as follows:

1. 100 lb. of fluxed rods contain 88% metal.
2. 100 lb. of fluxed rods deposits 46.2 lb. of useful metal.
3. Discard for fluxed rods = 88 × 15% = 13.2 lb. (2.1 in.)
4. No. of lb. of fluxed rods used = 88 − 13.2 = 74.8 lb.
5. Deposit efficiency of fluxed rods used = $\frac{46.2}{74.8}$ = 61.7%.

The sputter loss of fluxed electrodes varies accordingly to two items: (1) length of arc, (2) position of weld.

The sputter loss average for fluxed electrodes in all positions is as follows.

Size of Electrode	Position	Sputter Loss in %
5/32 in. dia.	Flat	25
5/32 in. dia.	Vertical	31
5/32 in. dia.	Overhead	32
3/16 in. dia.	Flat	24
3/16 in. dia.	Vertical	29
3/16 in. dia.	Overhead	30

The sputter loss in a 30-volt closed circuit arc, flat position, is 18% and in 40-volt arc, 38%. The rate of deposition is affected by the length of the arc; in a 30-volt closed circuit arc it equals 58 oz. per hr., and in a 40-volt closed circuit arc it equals 44 oz. per hr.

Currents Used

The size of the electrode determined the welding current used, which ranged from 135 amp. to 145 amp. for 5/32 in. dia. electrode and 160 amp. to 175 amp. for 3/16 in. dia. electrode. Straight and reversed polarity were used with these rods.

Gaging the Size of the Welds

The standard AMERICAN WELDING SOCIETY gages were used to check the welds so as to have them conform to designed dimensions. Each welder and supervisor was furnished with a set of these gages, which checked their own work; it was then rechecked by the welding inspector.

Inspection of Welds

To secure the highest quality welds, each welder was trained especially in the making of the various types of welds on this lighter, employing flux-covered electrodes before they started the actual production welds. Each welder had to pass the Bureau's regulation of depositing on a catenary type of specimen weld in all positions that average 60,000 lb. per sq. in. tensile strength. Besides the inspection of the welds with gages, the welding inspector checked every weld for cracks and porosity. Wherever any defects were found, they were chipped out and rewelded. Hammer tests were made by the welding inspector on each side of all important strength welds to uncover excessive internal strains in the welded joint. To check for the correct current at the arc, check tests were made periodically by the inspector so as to observe also for fusion, penetration and porosity in the structure of the weld metal.

Kind of Tack Welds

The proper designated dimensions were maintained in the connected section of the lighter by means of tack welds and small angle clips. It was essential to maintain a fair line construction throughout this all-welded ship, as the curvature of the shell required perfect alignment of all connected members to secure a tight joint. Tack welds 1 in. in length and $^3/_{16}$ in. in throat section were laid down and spaced 18 in. apart. These tacks are strong enough to hold the parts but weak enough to break when shrinkage stresses become excessive. When the size of these tacks is maintained, they are small enough to be fused in with the finished weld and maintain the proper designed dimension. The small angle clips were used wherever it was required to close up a considerable gap in the faying surface, and also where it was required to insure certain longitudinal and transverse members free movement. These angle clips consisted of 4 in. x 4 in. x $^3/_8$-in. angle, 4 in. long with a slot cut 2 in. long and 1 in. in width in the center of one leg through which a bolt was inserted, the head of which was welded to the shell plating. The opposite leg of the angle was welded to the transverse or longitudinal member, which was to be welded in place. This form of securing tight faying surfaces proved very satifactory in the construction of the lighter and aided greatly in maintaining the proper contraction in all the members which were free to move.

Spacing of Welded Increments

The length of the welded increments was standardized at 3 in., and the space between the increments was set at 3 in., making a set distance of 6 in. from the center of one increment to the center of the next. This size of increment and spacing is in conformity with the best known designed practice for this particular type of construction.

Use and Number of Welders and Burners

The main staff of welders had first-class ratings; they welded up the major portion of the ship while the tack welding was performed partly by first-class welders and apprentice welders who had graduated from the yard's Welding School and passed the qualification tests for welders. All the burning was performed by the oxy-acetylene cutters in the construction of the hull; it was to an advantage to have burners allotted to the shipfitters instead of combination welders and burners, as there always was sufficient work for the cutters to do without the addition of welding. The tack welders followed along after the shipfitters secured the proper faying surface for welding. A tack welder was allotted to a group of shipfitters while from two to four burners were required per day to take care of all the burning on the ship as it progressed, as mostly all of the fabricated parts were finished and cut to designed dimensions before leaving the ship-fitting shop.

Output of Welders

The total linear feet of welding and the average daily output per welder were as follows:

	Ship	Shop	Pier	Total
Total lin. ft. of welding	29,004	7652	675	37,331
Number of welders	713	242	62	1,017
Av. lin. ft. per 8 hr. per man	40.6	33.4	10.8	36.7

It will be noted that from the above table the ship welding per day per welder exceeded the shop production. The main reason for this is that on the ship the work was set up for the welders during the day and at night the welders were bothered by no other mechanics nor interferred with while they were welding. The majority of the welding on board ship was performed on piece-work basis and also the welding in the shop, but the shop men, even welding mostly on flat position welds, did not equal the average rate of the ship welders. The welding performed on the ship at the fitting-out pier showed the lowest average of linear feet of welding per day per welder. This is mostly due to the fact that the welders were welding up small parts all over the ship and completing most of the work for the electrician.

Shrinkage

The over-all shrinkage in length was checked before and after welding with a transit by the yard's surveyor. Bench marked and tape line measurements were used to secure the beam and frame movement of shrinkage. In comparing the over-all shrinkage in length with information available of other all-welded ships, we find that shrinkage secured is less than any other all-welded ship, except the YFD-7. The following shrinkage data on previously constructed all-welded ships are as follows:

Shrinkage of All-Welded Ship

Name	Made by	Length in Feet	Over-all Shrinkage, In.	Shrinkage per Foot of Length, In.
YG-16	Mare Island, U. S. N.	118	3.00	0.025
YMT-15	Boston, U. S. N.	65	3.25	0.050
YSD-7	New York, U. S. N.	102	0.375	0.0036
YF-221	New York, U. S. N.	120	1.8248	0.0152
Exp. Boat *Wilhelmshaven*,	German N.	46	0.887	0.019

The movement of all the shrinkage was toward midship and the beam shrinkage was toward the centerline. From the data on shrinkage obtained, the designing engineer will find the accompanying sketches to be of value in computing the stresses imparted into the framework of the ship by welding. The noted fact in all data compiled is that most of the shrinkages run nearly uniform for the same plate thickness and vary directly with the increase or decrease in plate size. The stresses in each size of weld can readily be calculated accordingly to the Hook formula, as $S = E \times \frac{1}{L}$, L being the length of plate checked within the gage marks, or $S = eE$ where

S = stress in lb. per sq. in.
e = change of length per unit length, or the ratio of change of length to total length
E = modulus of elasticity

In welding of the ship all the butts were welded progressively with the shell plating free to move, but if the edges of the shell plating were held rigid the full shrinkage of the weld would set up internal stresses within the weld which might become large enough to cause the weld to crack. As we find in the data secured, the shrinkage values in the weld are high and are sufficient in strength to crack any intermediate welding which would be undertaken after the initial welding had made the joint rigid. For example: maximum shrinkage of the butt joint A-1 was 0.165 in. If the plating were rigidly connected to the framing 14 ft. from the butt, the following results

would be obtained: $e = \frac{0.165}{28 \times 12} E = 30{,}000{,}000$;

$S = \frac{0.165}{28 \times 12} \times 30{,}000{,}000 = 14{,}700$ lb. per sq. in.

It is believed that much of this stress would be relieved by slack and buckles in the plate. If the shell plating be rigidly connected to the frame 2 ft. from the butt, the following results would be obtained: e becomes $\frac{0.165}{4 \times 12}$ $= 0.00344$, and we have $S = 0.00344 \times 30{,}000{,}000 =$ 103,200 lb. per sq. in. As this shrinkage stress is in excess of the strength of the weld metal, cracks will occur in the weld. The solution of this problem has been proved from practice, as cracks have occurred in similar butts which have been held rigid. It is readily conceived that if the welding is proceeded with in accordance with the practice established in the welding of this ship, the minimum amount of over-all shrinkage will occur.

Due to the variations secured in the shrinkage across the various sizes and types of joints, it is believed that in the construction of an all-welded ship, the only factor which can be used is the calculated shrinkage per foot of length secured from the over-all shrinkage, and this again will vary with the procedure of welding the ship.

In general, continuous welding gives rise to greater strains than interrupted welding.

On butt joints between plates of different thickness it is more difficult to secure a uniform shrinkage than between plates of equal thickness. Thin plates give the greatest amount of warping. To control the shrinkage and warping, the present system of completing the bulkheads in the shop and assembling as a unit on the ship will have to be revised to allow for the beam shrinkage. This must be accomplished by either leaving the center vertical seam of the bulkheads free to move or else setting the assembled unit in place and welding the same after the shell, deck, longitudinal and transverse framing have been completed. The question of the advisability of strengthening the all-welded bulkheads by the addition of transverse stiffeners should be experimented upon, as the solution of preventing the warping in bulkheads, it is believed, could be corrected by this method.

Adaptable Types of Welded Connections for Buildings

By GILBERT D. FISH

†Paper presented at Oct. 16, 1933, Meeting, Philadelphia Section, A. W. S., by Gilbert D. Fish, Consulting Structural Engineer, Westinghouse Electric & Mfg. Co.

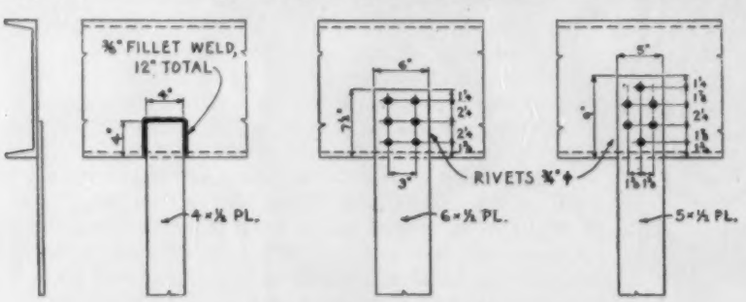
STANDARDIZATION of joints for steel-frame buildings has been carried to great lengths in riveting practice. It saves time in office, drafting room and shop, but it wastes a considerable amount of connection material and requires driving many extra rivets. This standardization has been somewhat liberalized in recent years to suit the increased variety of rolled-beam sections; standard beam connections are now commonly selected with reference not merely to beam depths but also to the reactions which must be sustained.

Welded joints have not been extensively standardized, partly because welding is fairly new in building construction, partly on account of the great variety of available forms and perhaps partly because engineers studying this subject doubt the economy of promoting convenience by radical curtailment of variety. Nevertheless, it is advisable to develop joint types of broad adaptability, having the greatest economy in labor and material consistent with wide application. Another way of stating this objective is to say that typical joints for extensive use should be designed to combine efficiency in individual cases with adaptability to a wide variety of loads, sections of members and space relationships of joined parts.

Building joints can be classified broadly as end connections for beams, column splices and miscellaneous joints. Beam connections are the most numerous class and the most important commercially, not in every building but in general, and most of the study directed toward improvement in joint design is devoted to this class. Column splices are simple and monotonous; it is not uncommon to use a single type for all the splices in a building. Miscellaneous joints, including all connections not covered by the other two headings, are too varied to permit all cases to be served by a few typical forms.

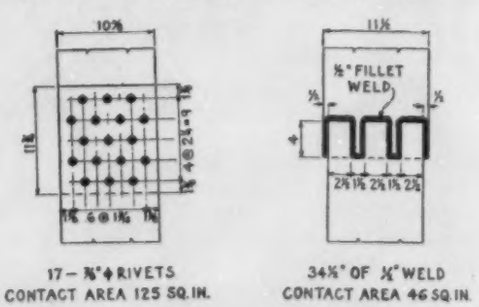
In this brief discussion of adaptable connection forms, several miscellaneous joints will be illustrated, a column splice of nearly universal applicability will be shown and the development of a highly adaptable beam connection will be described.

Among miscellaneous connections, lap joints play a prominent part. They are useful for hangers and truss members. Figure 1 shows an elementary form of



HANGER CONNECTIONS DESIGNED FOR 36 KIPS

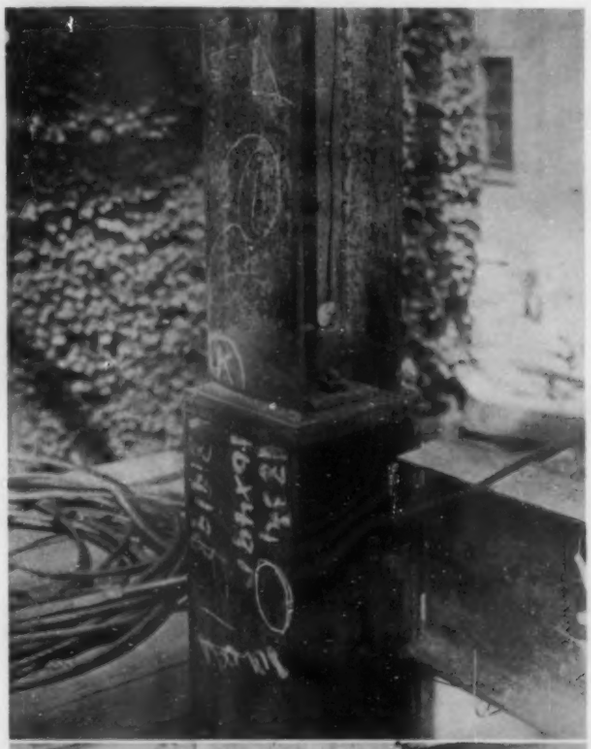
Fig. 1



LAP JOINTS DESIGNED FOR 138 KIPS

Fig. 2

Fig. 3—Column Splice



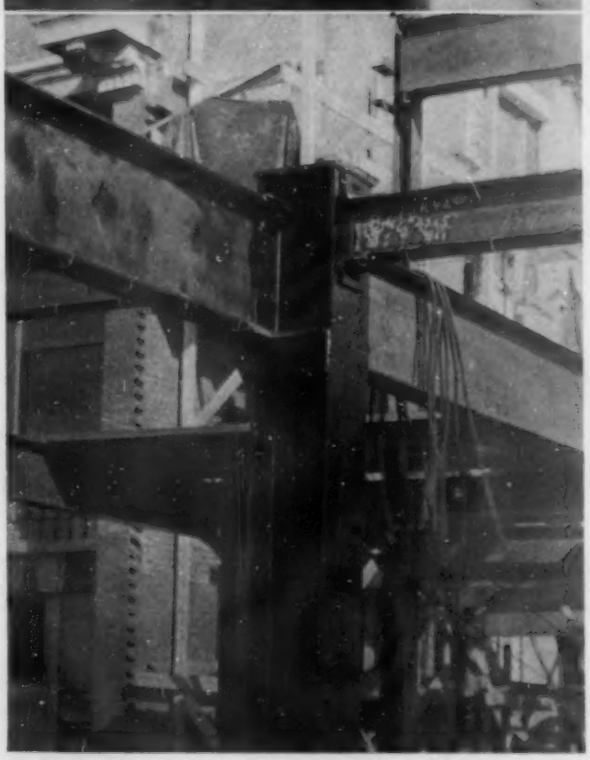


Fig. 4—Connections in Yale Medical Center

welded plate-hanger connection of lap type, in direct comparison with riveted connections designed for the same duty. No fabrication is needed for the welded connection, unless holes are provided for erection bolts.

Figure 2 shows a lap joint in which a slotted splice plate or gusset is welded to a member to transmit an axial load of tension or compression; the welds act mainly in shear, as do the rivets in the corresponding riveted joint shown in the same figure. Slotting the connection plate permits increase in the length of welding without increase of plate size and is an elaboration of the elementary design of Fig. 1; slotting is not worth while except for large loads.

Welding permits connecting a member directly to another even if they do not lap, provided they make contact or approach each other within $^1/_{16}$ in., or perhaps $^1/_8$ in. This is only occasionally advisable in beam-and-column framing, because it usually requires cutting beams to accurate lengths, but in pitched roof framing it is frequently very advantageous in eliminating intricate connection pieces and reducing the amount of welding. For hip-and-valley roofs it is generally sound practice to detail the members to make contact, or approach each other closely enough for direct welding, and to provide enough clip angles or bent plates to permit bolting the members into correct position ready for field welding.

Figure 3 illustrates a type of column splice which, with minor modifications, has been employed throughout a considerable number of buildings. It has been found equally suitable for small and large columns. The butt plate thickness is nominal in case the upper and lower columns have approximately the same web depth, but is designed to resist bending if the column flanges are out of line as in the illustration. This type of splice requires machined ends of columns, but avoids flange-splice plate and fillers.

End connections for beams must be designed to suit the relative positions and also the cross sections of the parts joined, for it would be generally impracticable to reverse the procedure and design the framework to suit the connections. It is sometimes both practicable and economical to modify the sections or change the positions of members for the sake of advantage in the connections, but with welding this is ordinarily a matter of convenience rather than necessity. Broadly, the problem is to provide a sufficient variety of economical joint types to suit all ordinary cases, keeping the number of types small in order to gain the greatest advantage from standardization.

The ideal of a universal form of beam connection is not nearly attainable; it probably would be if every beam were connected at each end to a vertical face having sufficient height and width to suit the purpose, if no coping or blocking were required to clear obstructions and if no other beam were in any case so located as to interfere. It is possible, however, to meet the requirements of all cases which commonly occur by means of a single type which is adaptable to a majority of cases and several less adaptable types which take care of the remainder. In practice there are uncommon cases which require or at least merit special designs, and it is unwise to carry the idea of classification and standardization to the extreme of using unsuitable standard types in such cases.

Seat angles can be used for a large proportion of beam connections to columns and for many beam connections to other beams, but they are rather heavy, they have a tendency to bend or tilt the supporting members, they cannot ordinarily be used for very heavy reactions unless reinforced by stiffeners and they are unsuitable for supporting thin-web beams having high shearing stress, because of the liability to web crippling. Furthermore, they are usually unsatisfactory unless accompanied by top-flange connections, because alone they fail to provide lateral bracing for the top flanges of the beams or general bracing for the framework. Seat angles combined with top-flange connections are very useful at

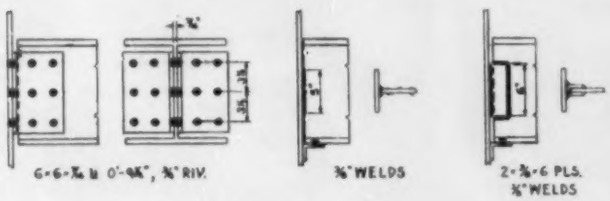
Fig. 5—Floor Framing, Yale Dormatories

Fig. 6—Welded T-Connections, Berkeley Dormatories, Yale

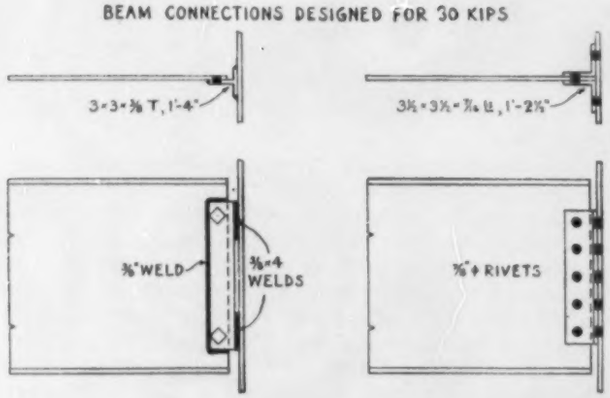
beam-to-column joints, for providing considerable bending resistance against wind forces and at the same time sustaining moderate vertical reactions (up to about 30 kips).

Figure 4 is a photograph which shows two quite different details of seat-and-top connections, each designed for a definite bracing moment and a definite vertical shear. These particular designs are two years old and would probably not be exactly reproduced now, but they represent a general type which is believed to have a proper place in building construction.

A class of beam connections generally better suited to transferring vertical beam reactions, but relatively ineffective in developing bracing moments, are web connections. There are many types in this class. The simplest consists of direct welding between beam and support; it lacks flexibility and is, therefore, subject to considerable secondary bending stress due to beam deflection, it is inapplicable unless the beam web is nearly in contact with the support and it includes no provision for temporary support or bracing during erection. A similar type, which avoids the need for close proximity of beam and support but which requires some connection material and more welding, consists of a pair of plates, shop welded to the web so as to project the required amount beyond it and field welded to the support. Either of these types can be supplemented, for erection purposes, by a small erection seat with erection bolts; in case the connection is to a supporting beam or girder, the beams being flush on top, the erection seat may conveniently be replaced by a plate projecting as a lug from the flange of the carried beam, as shown repeatedly in Fig. 5. Figure 6 compares two equivalent welded connections, of the types discussed in this paragraph, with a familiar type of double-angle riveted connection designed for approximately the same reaction and suited to the shallow, heavy beam shown. Although secondary bending stress, due to beam deflection, would be present in both of the welded joints, it would be insufficient to affect the ultimate shearing resistance if the beam web were not thicker than the $^{7}/_{16}$ in. indicated, because the beam web would yield slightly in the vicinity of the welds without yielding of the welds. On the other hand, the riveted joint would be free from danger due to secondary stress because of the flexibility of the angles, regardless of beam-web thickness, but with any thinner web than $^{7}/_{16}$ in. the bearing pressure of rivets on the beam web would exceed 30 kips per sq. in. at the load shown.



BEAM CONNECTIONS DESIGNED FOR 30 KIPS



BEAM CONNECTIONS DESIGNED FOR 42 KIPS

Fig. 7

Another type of welded web connection employs a pair of side framing angles. Such a connection, copied from riveting practice, is satisfactory in respect to providing reasonable stiffness without appreciable secondary stress and in affording convenient places for erection-bolt holes, and it is efficient when the angles are fairly long, but for connections to carry less than 50 kips this type is inefficient because of the necessary extra length and welding to resist the toggle action of the beam web tending to rotate the angles apart at the bottom.

Experience in drafting room, shop and field, with beam connections such as have been illustrated, showed that they could be applied with success and fair economy to a majority of cases arising in miscellaneous building

practice. Nevertheless, the exceptions for which special details had to be provided made joint designing and detailing too laborious and prevented extensive duplication of connection pieces and workmanship. After completion of a varied group of welded buildings at Yale University about two years ago, including almost every possible relationship of beam to supporting member and covering a range of reactions from about zero to several hundred tons, an attempt was made to classify and analyze beam connections, with the main object of developing a widely adaptable joint which should combine as many efficient characteristics as possible. It was realized that no sufficiently adaptable type would combine a sufficient range of vertical shear resistance with high resistance to bending caused by wind; therefore, wind bracing was considered as something to be added independently when required, but it was deemed essential that the connection without separate wind bracing should have enough stiffness to compare favorably with ordinary side-framing angles.

It was believed that, in order to be sufficiently adaptable, such a joint should serve to support I-beams, girder beams, H-beams, plate girders and channels; that it should connect them to column flanges, column webs or supporting beams, as required; that in cases of beam-to-column connections it should permit of moderate eccentricity, and in cases of beam-to-beam connections it should permit of moderate differences in top elevation of the connected beams and should not require the supporting member to project below the bottom flange of the other; that it should permit of coping or blocking the carried beam at top or bottom where necessary for clearance; that it should serve beams of all web thicknesses.

In order to be efficient, it was considered that the joint should require only a single connection piece other than erection bolts or a locking device; that it should be light and easy to fabricate; that the welds should be close to the meeting line of beam web and supporting surface; that there should be little or no welding devoted to erection purposes only or otherwise failing to contribute to the support of the final load; that provision should be made for easy and accurate erection, by erection bolts or other positive means; that the welds should be of the same thickness as the adjoining edges, to avoid need for gaging them; that beams should not have to touch or nearly touch the supporting members; that holes for erection bolts should not be required in both the joined members, and preferably not in either; that the joint should provide enough bending resistance to serve as stiffening for the building frame in structures not requiring special provisions to resist wind. Other desirable features were listed, but were either of minor importance or appeared inconsistent with some of those above mentioned.

A fairly close approach to most of these requirements has been realized in a T-connection now being used in the Berkeley Dormitory Quadrangle at Yale. In spite of the rather wide variety of cases presented by this decidedly irregular structure, this form of beam connection is being used for most of the beams in the job except outer wall beams and members less than 8 in. deep. The convenience of this typical joint has been very pronounced in the office and detailing room, and it has made shop work simpler than for earlier buildings of similar design. Erection is as easy as with other connections providing erection bolts and field welding is proceeding at a satisfactory rate. The quantities of connection material and welding are very moderate, comparing favorably with the lowest figures for other types of joint except direct welds.

Figure 7 shows a particular design of this type and compares it with a riveted connection of the same capacity. A rolled T is sheared to length, has two erection holes punched in its stem and is shop-welded to the supporting member along its vertical edges. The supported beam has its web punched with holes to match, but is not otherwise fabricated unless coping or blocking is required. In erecting, the beam is swung into place against the T's at the ends, the stem of each T being on the right of the beam web as the observer faces the joint; sometimes it is necessary to locate the T opposite hand, to permit erection or facilitate field welding, in which case the exception is noted by marking the position of the T on the erection plan. The stem of the T is field-welded to the beam web, this welding being all on one side of the beam.

Figure 8 shows two of these T-connections at close range. The T's are flexible enough to avoid secondary-stress problems but are stiff enough to brace buildings of moderate height. They do not involve the beam flanges and, therefore, permit coping or blocking or the addition of flange connections for wind bracing. The T-flange is narrower than a pair of angle legs and, therefore, fits a narrower space on the supporting member. Connections to column flanges can be considerably eccentric, because the T can be welded to the column even if it projects somewhat beyond the edge. The slight eccentricity of the T with respect to the beam which it supports is counteracted by a trifling extra amount of welding, its only material drawback being that the offset, equal to half the combined thicknesses of T-stem and beam web, must be allowed for in locating the T on the shop drawing of the supporting member.

The T's might be shop-welded to the beams instead of to the supports, but this would involve using T's with flanges wide enough to accommodate erection bolts. This has not been tried, but seems worth considering from the standpoints of slightly easier erection in tight places and avoidance of the small amount of overhead welding at the bottom edges of the T-stems.

Welding as an Aid to Modernization of Breweries

By D. S. LLOYD

†Paper presented at Fall Meeting, American Welding Society, Detroit, October 2, 1933. Mr. Lloyd is connected with the Dominion Oxygen Company, Limited, Toronto.

THE brewing industry is at present in the midst of a transition period. Equipment for the manufacture, distribution and merchandizing of beer is being modernized to take advantage of the great advances made in metal working. The legalization of beer in the United States is contributing greatly to these changes, particularly as the use of new metals and fabricating methods is so far advanced in this country.

The brewing of beer is fundamentally a biological process which remains unchanged. However, no two brands of beer are exactly alike, as small variations in the process of brewing cause differences in taste and color. In many instances the detailed procedures for the making of well-known beers have been passed down from generation to generation in the same family. Naturally this has led to the building up of traditions in the industry which resist changes in processing and this attitude is now reflected in the resistance of the older generation of beer manufacturers and consumers toward the adoption of radical changes in equipment.

The tremendous demand which must be rapidly supplied and the change in general attitude toward beer drinking caused by new legislation and the increasing tendency toward home consumption, have accelerated and will continue to promote the adoption of modern ideas in this industry. A discussion of the possible applications of oxyacetylene welding and cutting in the brewing industry naturally subdivides itself into three parts:

Manufacture, installation and maintenance of brewing equipment.

Manufacture and repair of distribution equipment.

Manufacture and installation of service equipment.

Until the last few years welding has been used in breweries mainly for general maintenance in the repair of broken parts. The extent to which welding can be applied is almost unlimited, and in the following a general outline is presented which shows many of the fields in which welding may become standard practice if the newer metals and alloys continue to grow in popular favor in the industry and if the brewers can be educated to appreciate the great advantages of this permanently leak-proof type of jointing.

The Brewing Process

A brief description of the process for making beer will serve as a general guide to equipment requirements. Figure 1 shows a very abbreviated brewery flow sheet. Malt (partially sprouted barley) is mixed thoroughly in a mash tun with hot water at proper temperature to form a liquor called wort. The wort is separated from spent grain and is then boiled in a kettle where hops are introduced to give flavor and add preservative substances. The brew is then strained off the hop leaves in the hop jack, cooled and placed in fermenting tanks in which the heat of fermentation must be controlled by refrigeration. After fermentation the beer is aged in refrigerated storage tanks from which it is filtered and either kegged or bottled. If bottled, the beer must be pasteurized.

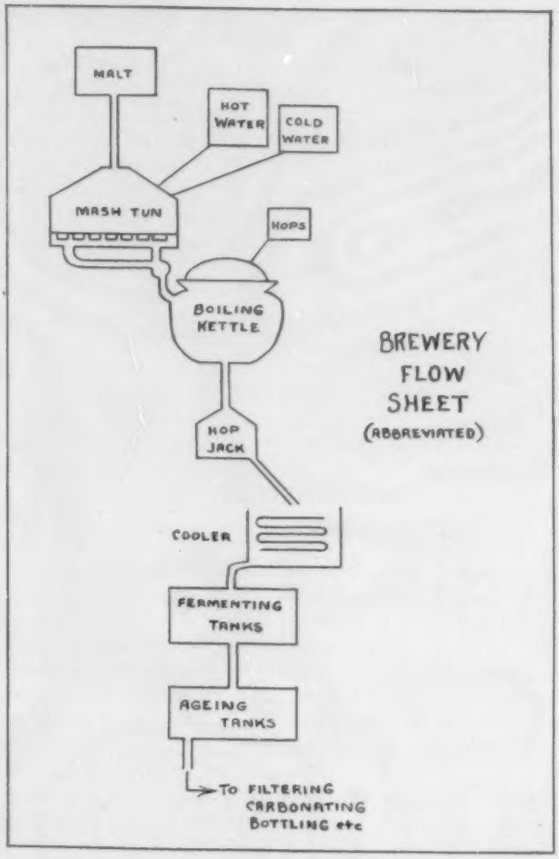


Fig. 1—Brewery Flow Sheet

Installation and Maintenance of Piping

The first and most important field for the general adoption of welding in breweries is piping. Thousands of feet of piping must be used, even in a small brewery, to supply steam, hot and cold water and refrigeration for the processing of the beer. Figure 2 gives a diagram showing the major piping required in one moderate-sized brewery. When it is considered that all the steam, hot and cold water and refrigeration piping, varying in size from $^1/_2$ in. to 6 in. or more, is usually steel, an obviously fertile field for welding is immediately presented. Most old breweries have had these pipe-lines installed with mechanical joints. The obvious advantages of leak-proof welded joints, permanently tight yet easy to remove or remodel, and which are now equal to or lower in first cost than any type of joint, should be impressed on brewery architects, consulting engineers and operators.

Process piping from the mash tun to the bottling machines has been almost exclusively copper with soldered or mechanical joints. That gas-welding can be used to advantage on much of this piping is quite evident. However, considerable resistance to the use of bronze-welded or copper-welded joints in this piping will probably be encountered due to the fact that these older types of jointing have been in use for generations. Probably the most effective way to promote the use of the oxy-

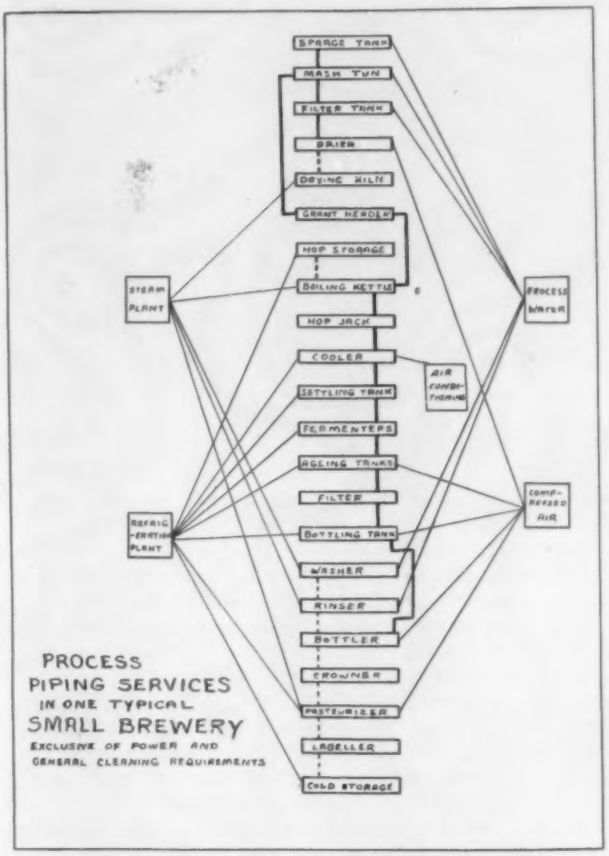


Fig. 2—Process Piping Services in Typical Brewery

acetylene welding blowpipe on this process piping would be to educate the brewers to the universal use of welding for both the maintenance and installation of steel piping. The unqualified satisfaction obtained with the welded joint in other lines would probably cause its eventual adoption in this field wherever it can be economically applied.

Monel metal, aluminum, stainless steel and other nickel alloys are now beginning to receive attention for parts of the process piping, particularly in the fermentation and storage cellars. The use of these metals in pipe-lines will undoubtedly follow their adoption for tanks and other equipment, and oxyacetylene welding will most certainly find a place in the joining of these lines and fabrication of fittings.

It should be noted that the chart in Fig. 2 outlines the pipe required in one particular brewery of moderate size. In addition there are almost innumerable other items of equipment for main or supplementary processes which are used in some breweries and which require piping for water, steam, refrigeration or other services. Some of the additional pipe-lines used can be visualized from the data given in Table 1. No attempt will be made to describe the applications of oxyacetylene welding and cutting in the manufacture and installation of equipment and piping in the power plant and refrigeration systems for breweries. It is sufficient to say that both these systems are most important and of comparatively large capacity and, therefore, add considerably to the possible applications of the welding process.

Air Conditioning

One of the most promising changes in the brewing industry from a welding standpoint is the increasing use of air conditioning. For years it has been known that infection of the beer by bacteria after leaving the boiling kettle may even be caused by impure air. It has been current practice to wash the air in most types of open coolers through which the beer passes before entering the fermenting cellars. There is now a decided tendency to extend this use of air conditioning to include both the fermenting and aging cellars, hop storage, stock house and keg racking and bottling rooms. Welding finds such favorable use in the fabrication and installation of air ducts and air control equipment that this field will undoubtedly develop considerably in the immediate future.

Process and Storage Tanks

From the brief description of the process of brewing beer given previously, it will be seen that the brewery has many problems parallel to those in most modern chemical plants where liquids are handled. Not only must care be taken to select equipment which will not corrode under the action of the hot and cold liquors, but unusual precautions must be taken to prevent variations in taste and turbidity. Above all, bacterial infection must be guarded against at all stages of the process.

These factors necessitate the use of materials which (*a*) will not corrode, (*b*) will not affect the taste of the beer, (*c*) will not cause turbidity and (*d*) can be readily sterilized after every brew. The fermenting, aging and storage tanks for Government measuring and bottling must always be made of materials which are above suspicion. These tanks were previously made of wood, coated inside with suitable pitch material to make them tight and to prevent the beer touching the wood. Since the beginning of this century, glass-lined steel tanks have increased in use. Lately, however, welded tanks made of aluminum have given satisfaction in Europe and stain-

Table 1—Additional Brewery Equipment Requiring Piping (Supplementing Fig. 2)

Equipment	Service Piping Required
Pneumatic malt Handling equipment	Steel piping for conveying malt and air piping for dust removal
Rice cooker	Process, steam and hot water
Pony masher	Process and water for moistening
Pfaff header	Process and water
Lauter tub	Process and heating
Mash filter	Process and heating
Spent grain hopper	Process for pumping spent grain
Hop strainer	Process and heating
Hop extractor	Process and steam
Wort pump	Process and steam
Hot wort tank	Process
Settling tank	Process
CO_2 liquefying plant	Process piping to scrubbers, compressors, condensers, etc.
Coolers	Process, refrigeration and air conditioning
Carbonator	Process and CO_2 piping
Racker	Process and compressed air
Government tanks	Process and refrigeration
Keg washer	Water
Shavings washer	Water
Filtermass washer	Water
Keg pitching machine	Compressed air
Surface cooler	Process and air conditioning
Keg brander	Gas for heating
Steam power plant	Interconnecting piping for boilers, pumps, feed water heaters, etc.
Refrigerating plant	Interconnecting piping for pumps, condensers, cooling coils, etc.
Water system	Heating coils for hot water tanks; interconnecting piping from city water supply, well, cold and hot water storage, water treating apparatus and cleaning and general plant service

Table 2—Present Trends in Brewery Tank Construction

Brewery Processing Tanks	Present and Past Usual Construction	Welding Possibilities
Grain storage bins and scale hoppers	Wood, steel, concrete or masonry blocks	All-welded steel
Rice cooker (atmospheric and pressure types)	Steel	All-welded stainless steel
Mash tun Mash tub Lauter tub Mash filter	Cast iron, steel or wood	Welded mild, stainless or stainless-clad steel
Boiling kettle	Steam jacketed or direct fired; copper riveted and soldered	Welded aluminum or copper
Hop jack	Wood or steel	All-welded stainless steel
Hot and cold water tanks	Wood or steel	Welded steel
Hot wort tank	Wood, steel (coated) or copper	Welded copper or aluminum
Settling tank	Wood or steel (coated)	Welded copper or aluminum
Fermenting tanks	Wood, concrete, glass-lined steel, mild steel (coated) or enameled	Welded aluminum, stainless steel, stainless - clad steel
Storage, aging and government tanks	Wood, concrete, glass-lined steel, mild steel (coated)	Welded aluminum, stainless or stainless-clad steel

less steel and some nickel alloys have been tried with good success.

Undoubtedly, the largest field for welding and cutting on this processing equipment is in the fermenting and storage tanks, of which there are usually dozens in every brewery. The welding industry should, therefore, watch with attention the increasing use of these new metals in brewery tank construction and place before consulting engineers, architects, tank manufacturers and operators in the brewing industry the salient facts regarding welded construction so they will take full advantage of the use of this improved method of jointing.

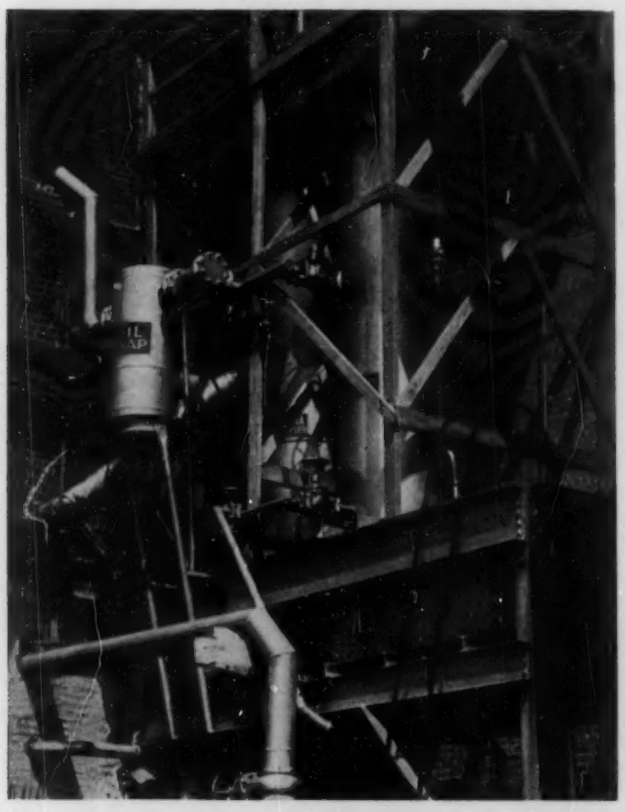


Fig. 3—Gas-Welded Ammonia, Condensers, Oil Trap and Allied Piping Are Ideal for Brewery Service

Fig. 4—Sugar Pan Fabrication Has Become Routine Work for Two Welders

A list of the major process and storage tanks found in breweries is given in Table 2. It will be noted that the cooking equipment has previously been made mostly of copper, and this has been true for generations. Undoubtedly tradition and the ever-present hesitation of the brewer to change any of the materials coming into direct contact during processing, will make it difficult to apply welding to any great extent on this equipment in the immediate future. As welding on other brewery equipment becomes more general and its advantages are proved to the brewer by long years of service, demands will undoubtedly be made for all-welded construction.

Material-Handling Equipment

It is not necessary in this paper to go into detail about the uses of oxyacetylene welding and cutting in the manufacture and maintenance of material-handling equipment. Grain in large quantities must be unloaded at ground level and raised to the malt storage bins, then screened, ground and weighed before processing. Spent grain must be dried and bagged. The keg and bottling departments require innumerable devices to automatically handle the cleaning, sterilizing, filling, crowning, pasteurizing, labeling and boxing of the product. Welding is being more and more extensively used on this type of equipment. The greatest application of the process can be found by cooperating with the manufacturers of this equipment in the first place. Maintenance and repair are, of course, greatly facilitated by the use of the blowpipe as is the case in every modern manufacturing plant.

Distribution of Beer

As everyone knows, there are two methods of transporting beer to the consumer. Draft beer is delivered in kegs and must be kept cold. Bottled beer is pasteurized before leaving the brewery and may, therefore, be sold like any other bottled commodity. Beer kegs have for generations been made of wood and have been lined with pitch coatings in the same manner as the storage tanks mentioned before. However, reports state that in the past few years over 600,000 steel barrels have been placed in service in Germany alone, and it is well known that thousands of steel beer barrels are being produced every

Fig. 5—Grain Pipe Fabricated with Extended Lateral Joints to Facilitate Cleaning by Ramrod

day in United States barrel plants. Aluminum barrels have also been successfully used in Europe and are being introduced into this country at present.

If the experience of other industries, such as the compressed gas industry, concerning the great advantages in cost of distribution through lightening the container, is any criterion, the transition to the metal beer barrel seems ultimately inevitable. Double-walled, insulated steel barrels seem to be the ones most favored at the present time. They are about 20 per cent lighter than wooden kegs and are designed to have equal resistance to temperature changes. If the internal wall is made of mild steel, the barrel must be pitch coated. If the inside is stainless steel, the initial cost is greater but the coating is unnecessary and cleaning costs are reduced.

Single-walled aluminum and stainless steel barrels have been used to some extent in Europe. Beer transported in such containers must be kept at more uniform temperatures than when wood or insulated double-walled metal is used, or the beer must be pasteurized. The single-walled barrel has the advantages of lighter weight, lower initial cost than the double-walled barrel without coating and lower maintenance expense due to easier cleaning and repair. It is possible that when and if refrigerated trucks are used for beer delivery and where the retail establishments are equipped with proper refrigeration, the single-walled barrel will come into more general use.

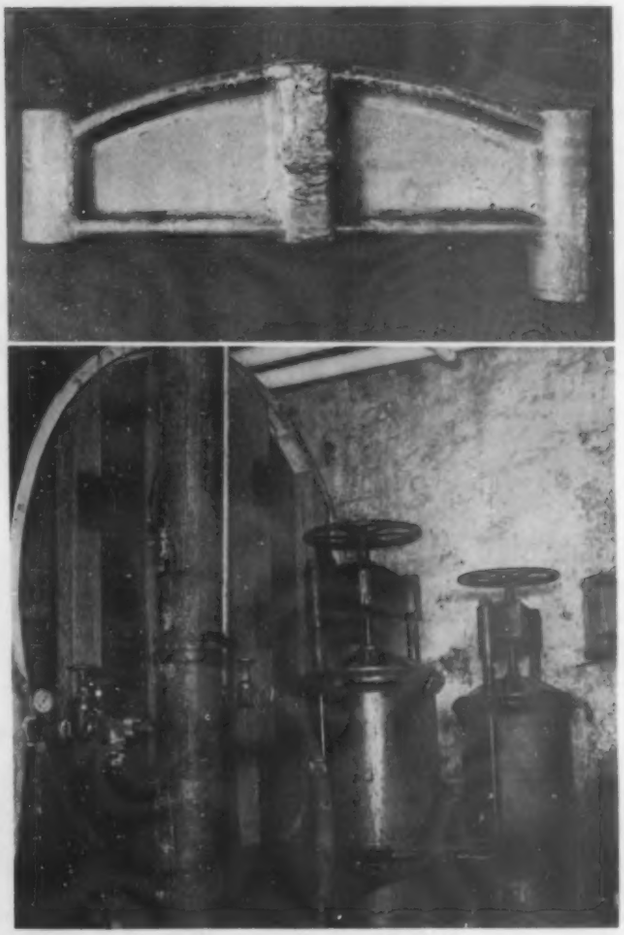
What type of barrel the brewing industry will eventually use is a matter of conjecture on which no brewing executive will express an opinion. Advertising and the opinion of the public may have a retarding effect on the use of metal barrels, but should the economies which are now claimed be substantiated in the next few years the continued use of oxyacetylene welding in the fabrication of barrels seems assured.

The use of tank trucks and tank cars for the transportation of beer in bulk to subsidiary bottling plants is also receiving considerable attention. This naturally opens another field for oxyacetylene welding in the fabrication of the tanks, especially as aluminum is satisfactory for this service and seems to be preferred because of its lightness and the extra pay load which may be carried.

The maintenance and repair of trucks and trailers used in transporting beer is of importance to every brewery and offers hundreds of opportunities to effect economies by the use of oxyacetylene welding and cutting.

Fig. 6—This Old Timer, a Copper Yeast Ladle, Has Been Kept in Service by Bronze-Welded Handle Repair

Fig. 7—Filter Press Yokes Reclaimed by Bronze-Welding Are Stronger and Withstand Sudden Pressure Shock



Beer Dispensing Equipment

Radical changes and improvements have been made in the manufacture of furniture and fixtures for the dispensing of food products. What the modern cafeteria is to the old-fashioned lunch counter the new tavern is

Fig. 8—Repairing an Aluminum Lid for a Beer Bottling Machine

to the bar of years ago. These changes have been brought about mainly through the development of new rust-resisting metals. Aluminum, monel metal, stainless steel and other nickel alloys have made it possible to beautify the fixtures and dispensing equipment and, at the same time, to increase the ease with which cleanliness and the highest standards of sanitation may be maintained.

The plants of the manufacturers of metal furniture and store fixtures offer fertile fields for the application of welding and cutting and these have already been widely developed. The increase in business enjoyed by these plants due to the legalization of beer offers an excellent opportunity to the welding engineer to render service to an old customer in applying welding to an even greater extent in the design and fabrication of the new fixtures which will be demanded by beer retailers.

The design and installation of refrigeration systems for these new taverns also offers some opportunities for the use of welding. The larger establishments will undoubt-

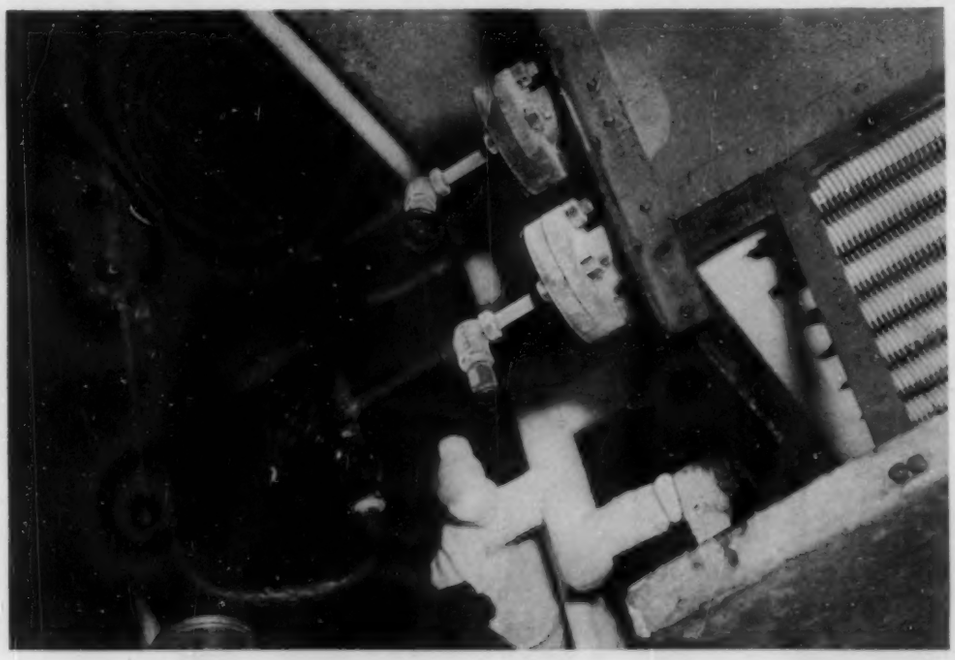


Fig. 9—Air-Cooling Unit for Aging Cellar Is Hooked Up with All-Welded $^{1}/_{2}$, $^{3}/_{4}$ and $1^{1}/_{2}$-In. Piping for Both Gas and Liquid Ammonia

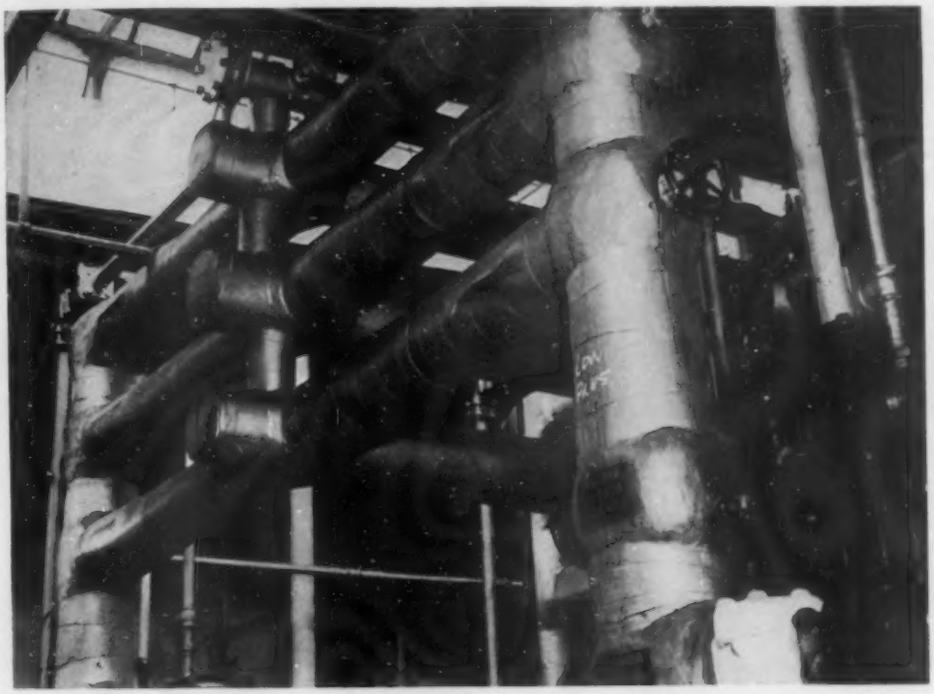


Fig. 10—Refrigerator Ammonia Headers in Engine Room Were All Fabricated by the Brewery Welders

edly find it economical to install a central refrigeration plant with special storage rooms for draft beer and piping to the coolers in the dispensing fixtures. This will produce a field for pipe welding especially when installations must be made in restricted quarters where a permanently leak-proof system is essential. The beer piping, usually copper, may also be of monel metal and can be quickly and economically brazed on the job, thus eliminating the use of many fittings. This field of application has an advantage in that no traditional prejudices are likely to impede the introduction of changes in methods of installation.

Maintenance and Repair

Mention has been made in the preceding paragraphs in several instances to routine welding and cutting operations which are almost universally accepted as the most economical methods of maintenance in any plant. It should be pointed out that with the rehabilitation of old breweries in the United States, coupled to the experimental use of new metals, the opportunities of economically employing welding and cutting equipment for maintenance will be greater in the next few years than has been the case in the past. In Canada there has been comparatively little new construction of brewery equipment due to the low cost of used equipment which could be imported. This is now eliminated and undoubtedly the manufacturers of brewery equipment on this continent will continue to be busy for years. In the meantime, the old plants which are in operation must be kept running.

Conclusion

The installation and maintenance of steel service piping offers an immediately profitable field for oxyacetylene welding and cutting in both new and old breweries.

Air conditioning, which offers many chances for applying welding, is increasing in use throughout the modern brewery.

The largest field for the use of welding in the manufacture of process equipment is dependent on the adoption of the new corrosion-resisting metals such as aluminum, stainless steel and other alloys.

The radical changes in beer distribution equipment through the use of metal barrels, tank trucks and tank cars offers a profitable addition to the opportunities for welding in this industry.

Oxyacetylene welding and cutting can be used to a much greater extent than heretofore in the maintenance and repair of machinery and equipment in existing breweries and in the manufacture and installation of material-handling equipment in the brewery and service fixtures in the taverns, restaurants and other retail establishments.

Who knows but that a few years from now you may be sitting in an ultra-modern, clean, airy tavern, in an all-welded chair with your elbows on a welded table. Your favorite beer has been brewed in a modern brewhouse which is equipped throughout with welded metal processing equipment and piping. From the shiny metal storage tanks at the brewery your beer has been directly passed into an all-welded refrigerated tank truck unpasteurized, from which it was delivered to the welded storage tanks in the refrigerated cellar below you. Such handling of your favorite brew, through welded equipment, will probably cut the cost of manufacture and distribution so your stein will be larger for the same price. Wouldn't it taste better to you?

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